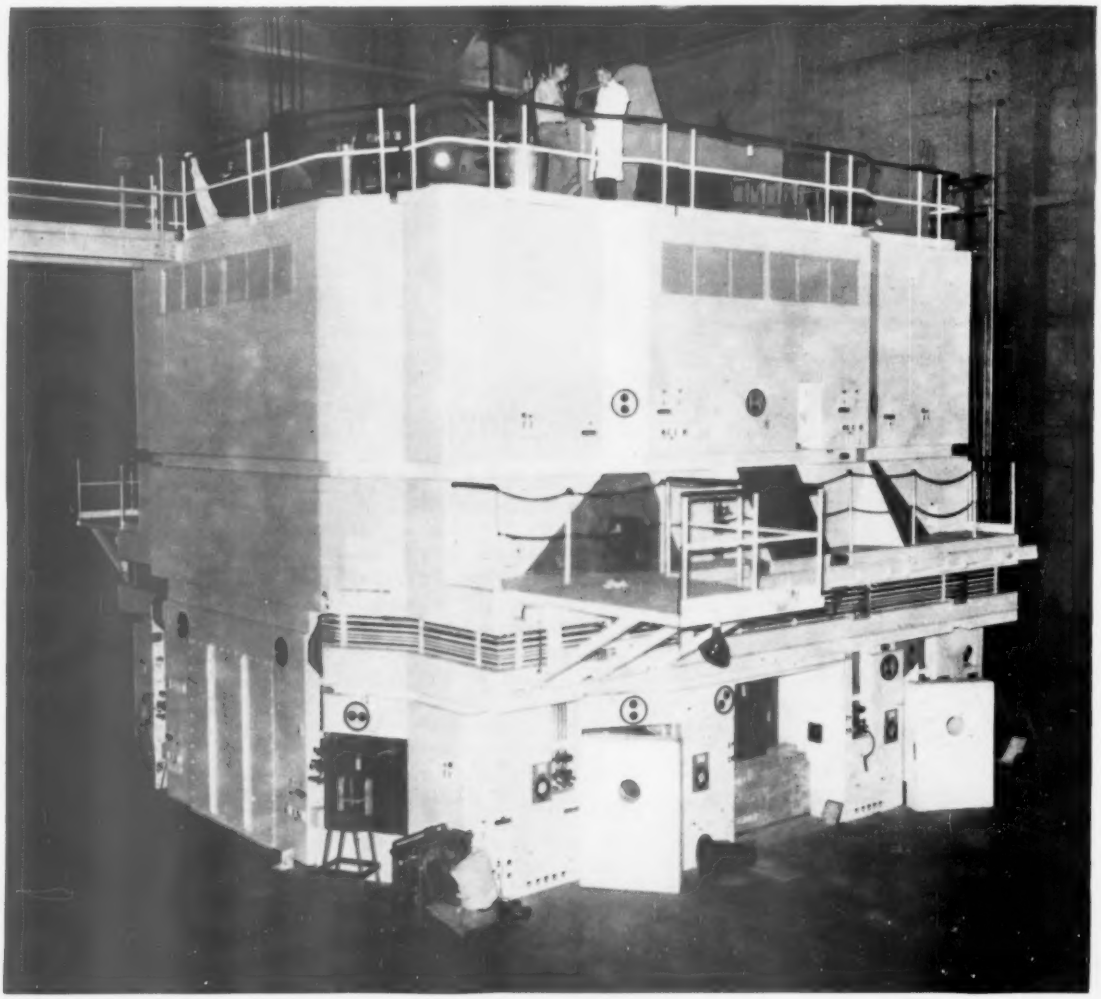
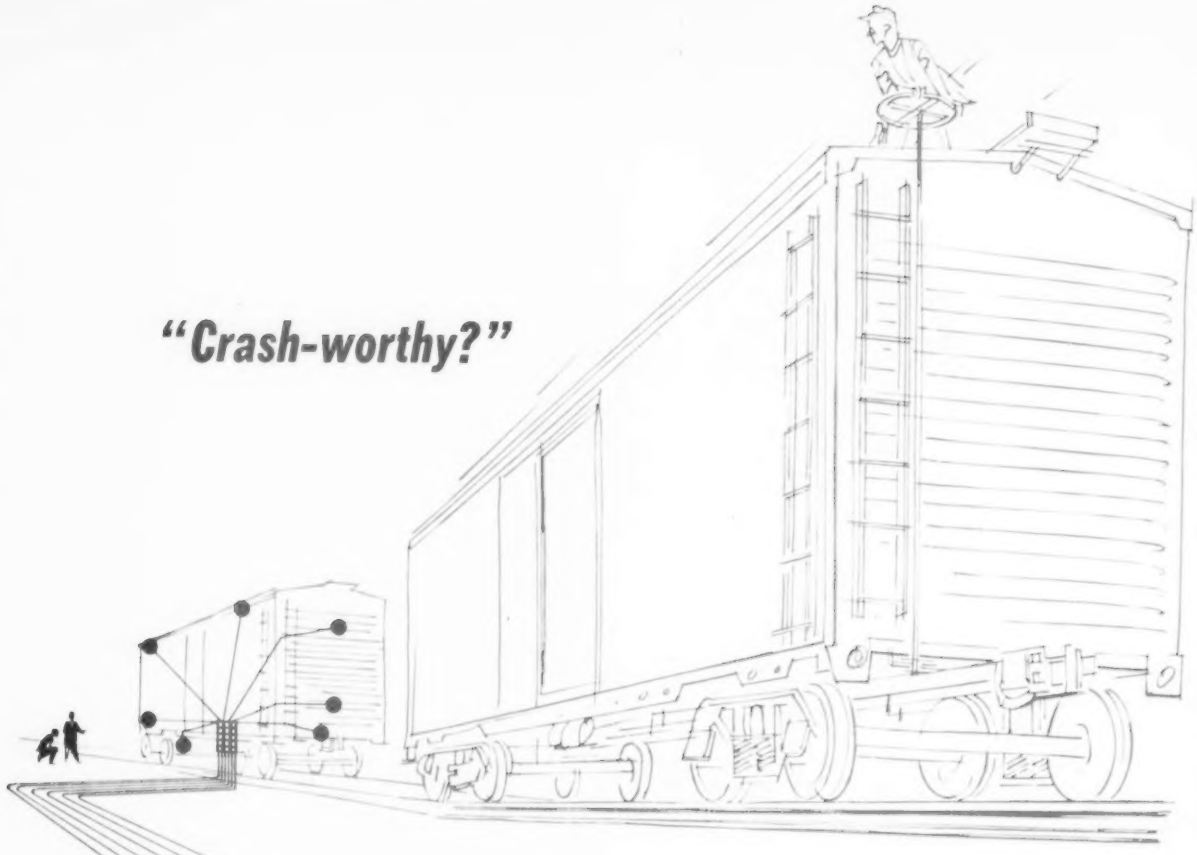
NUCLEONICS

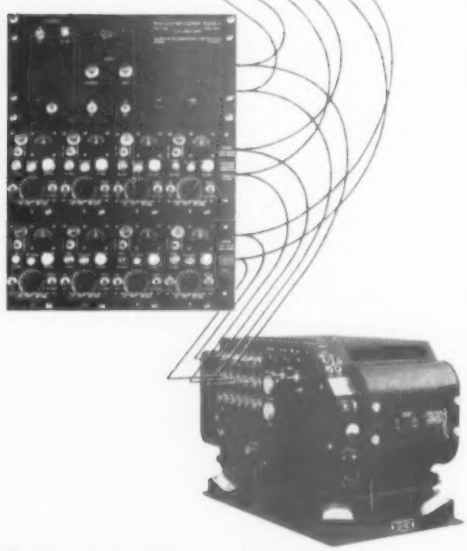
March 1953



Materials Testing Reactor, Arco, Idaho, reached full power in May, 1952, and is now in full use for studies of the effects of radiation on materials considered promising for new reactors. How the reactor project was organized and staffed is described on page 10

A McGRAW-HILL PUBLICATION ★ SEVENTY-FIVE CENTS





Pre-check with Consolidated Instrumentation

WHAT happens to structural members and car-body components when freight cars are subjected to the shock impacts and buffeting of hump-yard switching?

To determine stress distribution and to evaluate the effectiveness of shock protection devices, the Pullman-Standard Car Manufacturing Company selected a Consolidated 5-114 Recording Oscillograph, System D Amplifiers, and Bridge Balance as basic recording instruments.

Freight cars, loaded with sand and steel blocks at gross weights ranging from 46,400 pounds (empty) to 164,000 pounds (fully loaded) crashed together 185 times at speeds up to 10 miles per hour.

In this way the dynamics of simultaneous shocks, some as brief as one five-thousandth of a second, were permanently recorded in visual form. From such data will come design changes, giving protection against shock and vibration damage. Thus an improved product is achieved.

Consolidated Engineering
CORPORATION
300 North Sierra Madre Villa, Pasadena 15, California

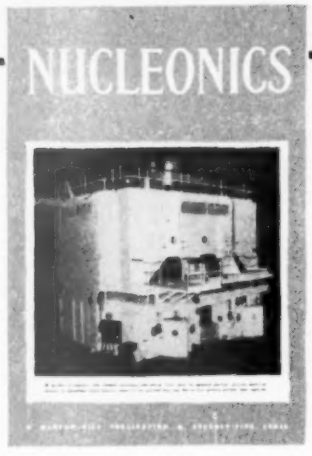
Sales and Service through **CEC INSTRUMENTS, INC.,** *a subsidiary with offices in: Pasadena, New York, Chicago, Washington, D. C., Philadelphia, Dayton.*

analytical instruments for science and industry

Dynamic Recording Systems

such as the one shown here are designed and manufactured by Consolidated. Variations in the arrangement of the equipment are infinite. Applications are widely varied throughout industry and the sciences. A typical recording system includes pickups, amplifiers or bridge balances, and a recording oscillograph. Write for Bulletin CEC 1500B-X5

Want more information? Use post card on last page.



MARCH • 1953

Vol. 11, No. 3

Organization and Staffing of the Materials Testing Reactor Project... 10
R. L. DOAN

The Half-Lives of Several Radioisotopes... 14
E. E. LOCKETT and R. H. THOMAS

Facilities for Gamma Irradiation... 18
BERNARD MANOWITZ

The Radiation Tolerance of an Adult Wasp... 21
ROBERT L. SULLIVAN and DANIEL S. GROSCH

A Simple Pulse-Amplitude Analyzer for Low Counting Rates... 24
K. KANDIAH

Gamma-Neutron Radiation Chamber for Radiobiological Studies... 28
HOWARD H. VOGEL, JR., ROLAND A. BLOMGREN, and NILS J. G. BOHLIN

Extending the Efficient Range of G-M Counters... 32
W. C. PORTER

Measurement of Reactivity... 36
JACKY WEILL

Recent Instrument Developments in England... 40
DENIS TAYLOR

Preliminary Report on Anemia in Mice Resulting from Irradiation of the Exteriorized Spleen... 44
BRUCE ALLEN

An Improved Wide-Range Radiation Instrument... 46
G. M. BURGWALD and L. REIFFEL

Preparation of Tagged Spherical Clay Particles... 49
W. S. GINELL and G. P. SIMON

Cross Sections

Interlocking Concrete and Lead Blocks for Radiation Shielding... 52
CLARK GOODMAN and GARDNER A. NORTON

Preparation of Microautoradiographs with the Use of Stripping Film... 54
W. E. LOTZ and P. M. JOHNSTON

Special Equipment for C^{14} Work... 56
B. M. TOLBERT, N. GARDEN, and P. T. ADAMS

Methods for Intracavity and Interstitial Administration of Radioactive Colloidal Gold... 60
J. E. STAPLETON and W. J. WINGO

An Improvement in the Victoreen 1,000-r Thimble Chamber... 62
C. S. SIMONS

Departments

EDITORIAL..... 9
BOOKS..... 64
LETTERS..... 68
NUCLEONIC EVENTS..... 70
PRODUCTS AND MATERIALS..... 76

JEROME D. LUNTZ, Editor
Ethel Pelzer, Associate Editor
C. J. Mosbacher, Jr., Associate Editor
Alan R. Liss, Assistant Editor
Thomas L. Cramer, Assistant Editor
Nancy E. Purves, Editorial Assistant
Harry Phillips, Art Director
Jack Gordon, Associate Art Director
George B. Bryant, Jr., Washington Office
Joseph Van Denburg, Jr., World News

KEITH HENNEY, Editorial Director

H. W. MATEER, Publisher
WALLACE B. BLOOD, Manager
R. S. Quint, Buyers Guide Manager
N. F. Cullinan, Promotion & Research
D. H. Miller, J. Girdwood, New York
Wm. S. Hodgkinson, New England
Warren W. Shew, Philadelphia
C. D. Wardner, Chicago
J. L. Phillips, Cleveland
T. H. Carmody, R. C. Alcorn, San Francisco
Carl W. Dysinger, Los Angeles
Ralph C. Maultsby, Atlanta
J. E. Blackburn, Jr., Director of Circulation

NUCLEONICS (with which is consolidated "Atomic Power" and "Atomic Engineering"), March, 1953, Vol. 11, No. 3. Publication Office: 212 East York St., York, Pa.; Editorial, Advertising, and Circulation Offices: 330 W. 42nd Street, New York 36, N. Y. Published monthly by McGraw-Hill Publishing Company, Inc. Entered as second class matter December 17, 1947, in the Post Office at York Pa., under the act of March 3, 1879. Copyright 1953 by McGraw-Hill Publishing Company, Inc. All rights reserved. Curtis W. McGraw, President; Williard Chevalier, Executive Vice President; Joseph A. Gerardi, Vice President and Treasurer; John J. Cooke, Secretary; Paul Montgomery, Senior Vice President, Publications Division; Ralph B. Smith, Vice President and Editorial Director; Nelson Bond, Vice President and Director of Advertising; J. E. Blackburn, Jr., Vice President and Director of Circulation. Allow at least one month for change of address. All communications about subscriptions should be addressed to Director of Circulation, 330 West 42nd Street, New York 36, N. Y. Price per copy $0.75. Subscription rates United States and U. S. Possessions $8 for 1 year, $12 for 2 years, $16 for 3 years. Canada, $10 for 1 year, $16 for 2 years, $20 for 3 years. Latin America, $15 for 1 year, $25 for 2 years, $30 for 3 years. All other countries, $20 for 1 year, $30 for 2 years, $40 for 3 years. Member of ABC. Member of ABP

Use These RAYTHEON SUBMINIATURE TUBES

FOR RADIATION INSTRUMENTS OF ATOMIC ENERGY COMMISSION DESIGN

RAYTHEON*
CK 1034
Radiation Counter

50 ua @
5 Roentgens/HR

RAYTHEON*
CK 1035
Radiation Counter

50 ua @
500 Roentgens/HR

*700 Volt Operation Self Quenching Halogen Filled Long Life

Each Tube Will Drive A 50 ua Meter Without An Amplifier

RAYTHEON
CK 1036
Cold Cathode Rectifier

Half Wave Gas Filled 100 ua Average Current
5 ua Max. Inverse Current At —1000 V.
1500 V. Peak Inverse

RAYTHEON
CK 1037
Voltage Regulator

Corona Discharge Type
700 Volt Regulating Voltage
15 Volt Regulation
5—100 ua Range

These tubes developed for A.E.C. by Raytheon Mfg. Co. All tubes shown actual size

RAYTHEON Quality Nucleonic Tubes include:

For complete description of an instrument read "Geiger Counter For Civilian Defense Use", NUCLEONICS, June, 1950; or "An Inexpensive, Wide Range Gamma Ray Geiger Survey Meter," A.E.C. Publication NYO 1538.

- RADIATION COUNTER TUBES
- VOLTAGE REGULATOR TUBES
- HIGH VOLTAGE RECTIFIER TUBES
- ELECTROMETER TUBES
- SUBMINIATURE AMPLIFIER TUBES

RAYTHEON®
Excellence in Electronics

RAYTHEON MANUFACTURING COMPANY
Special Tube Section

Newton, Mass. Bigelow 4-7500
Chicago, Ill. NAtional 2-2770
New York, N. Y. WHitehall 3-4980
Los Angeles, Calif. Richmond 7-5524

General Ceramics' high frequency SOFT MAGNETIC FERRAMIC* CORES

*TRADEMARK

Specified with Confidence for–

HIGH PERMEABILITY
LOW LOSS FACTOR
HIGH EFFICIENCY
LIGHT WEIGHT

The Most Complete Line of Ferrites –for Commercial and Military Electronics

CUP CORES
EI CORES
TUNING CORES
TUNING SLUGS
TOROIDS
SPLIT RINGS
"C" CORES
"U" CORES
TV COMPONENTS
ANTENNA RODS

Ferramics offer many outstanding advantages. These widely adopted magnetic core materials have reduced assembly time by eliminating laminations in inductive components, cut costs and reduced space requirements by replacing tubes in digital computers, and revolutionized microwave transmission design by use of gyrator effect. Ferramics have improved designs in numerous other equipments, and have resulted in the development of basically new techniques in still others. Current research indicates still greater gains to come. The complete story on Ferramics is available without obligation.

— IF YOU NEED ENGINEERING ASSISTANCE ON SPECIFIC PROBLEMS

The General Ceramics technical staff will be happy to consult with you. Just call or write Sales Engineer, Ferramics Division.

TABLE OF MAGNETIC PROPERTIES OF FERRAMICS

PROPERTIES	UNIT	A-106	B-90	C-139	D-226	E-237	G-254	H-419	H1-1102	I-141	J-472
Initial Perm. at 1 mc/sec	–	20	95	250	410	750	410	850	550	900	330
*Max. Perm.	–	100	183	1100	1030	1710	3300	4300	3800	3000	750
*Sat. Flux Density	Gauss	1500	1900	4200	3100	3800	3200	3400	2800	2080	2900
*Residual Mag.	Gauss	1000	830	2700	1320	1950	1050	1470	1500	700	1600
*Coercive force	Oersted	5.0	3.0	2.1	1.0	.65	.25	.18	.35	.30	.80
Temp. Coef. of initial perm.	%/°C	15	.04	40	.30	25	1.3	66	.80	.30	.22
Curie Point	°C	300	260	330	165	160	160	150	125	70	180
Vol. Resistivity	ohm-cm	1×10^7	7×10^7	2×10^4	3×10^7	4×10^7	1.5×10^8	1×10^4	2×10^4	2×10^5	5×10^7
Loss Factor: At 1 mcs/sec	–	.0005	.00016	.00007	.00005	.00008	.00008	.00030	.0004	.0003	.000055
At 5 mcs/sec	–	.0007	.0011	.0008	.0012	.002	.00075	.00155	.001	.005	.0004

*Measurements made on D.C. Ballistic Galvanometer with Hmax = 25 oersteds. Above data based on nominal values

AT THE I.R.E. SHOW BOOTH #1-506

GENERAL CERAMICS & STEATITE CORPORATION — STEATITE INSULATORS

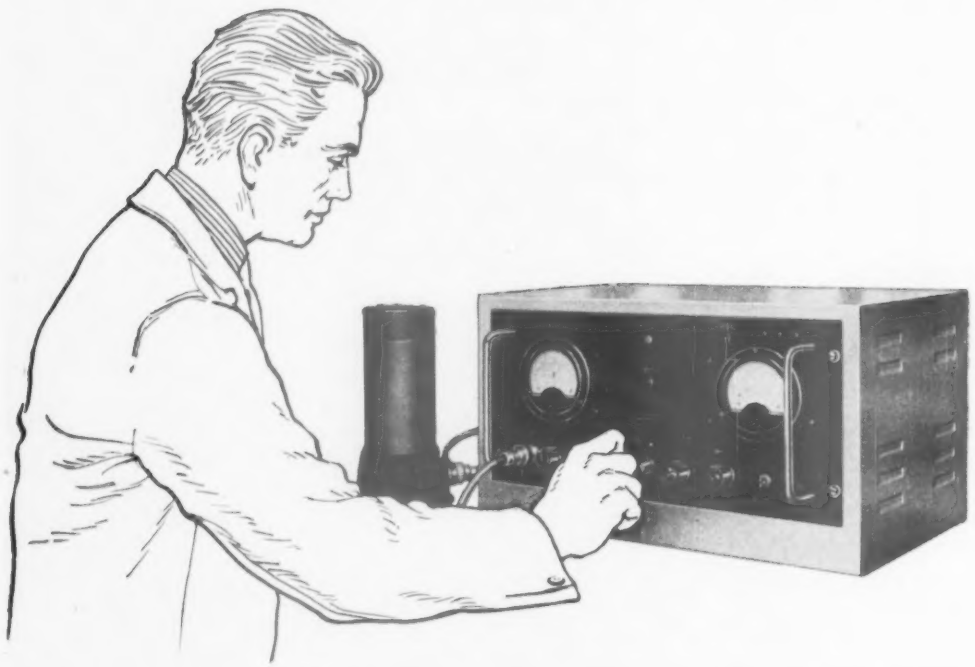
General CERAMICS and STEATITE CORP.

Perth Amboy 4-5100

GENERAL OFFICES and PLANT: KEASBEY, NEW JERSEY

MAKERS OF STEATITE, TITANATES, ZIRCON PORCELAIN, FERRAMICS, LIGHT DUTY REFRACTORIES, CHEMICAL STONEWARE, IMPERVIOUS GRAPHITE AND FERRAMIC MAGNETIC CORES

EKCO TYPE N522 RATEMETER



This is a precision counting-rate meter incorporating an input amplifier and a built-in variable high-voltage supply. It requires only the addition of a G.M. tube or scintillation counter to form a complete counting equipment. This new instrument is a development from the Ekco type 1037 which it replaces.

SPECIFICATION

INPUTS. The unit operates from positive pulses within the range 5v to 50v. An amplifier is provided for use with G.M. tubes and has switched gains of X2, X10 and X50; this operates from negative pulses.

DISCRIMINATION AND PARALYSIS. The discriminator permits only those pulses whose amplitude exceeds the pre-set level to be counted, this level being indicated on a 3½" meter. The Ratemeter can be rendered inoperative for pre-determined periods of 5 microseconds, 200 microseconds or 5 milliseconds after receipt of a pulse.

RANGES. Eight ranges are provided giving the following full-scale rate readings:—
3, 10, 30, 100, 300, 1000, 3000, and 10,000 pulses per second.

INTEGRATION. A series of integrating time-constants is provided, extending to 80 seconds.

ACCURACY. For steady-rate counting the circuit accuracy is better than ± 1% and that of the meter is better than ± 1% above mid-scale.

HIGH-VOLTAGE SUPPLY. Two ranges, variable from 250 to 1000 volts and 500 to 2000 volts. Stability ± 0.5% for ± 10% mains variation. The maximum output current is 80 microamps up to 1500 volts decreasing to 10 microamps at 2000 volts.

EXTERNAL POWER SUPPLIES. Power is available for operating an external quench unit or Scintillation counter.

MAINS INPUT. 110-120 volts and 200-250 volts, 40-60 c/s.

EKCO ELECTRONICS

SCALING UNITS · SCINTILLATION COUNTERS · COUNTING RATEMETERS · RADIATION MONITORS · VIBRATING REED ELECTROMETERS · G.M. TUBES · LEAD SHIELDING CASTLES · LINEAR AMPLIFIERS · COMPLETE COUNTING INSTALLATIONS · ACCESSORIES

U.S. Sales & Service :—

AMERICAN TRADAIR CORPORATION, CHRYSLER BUILDING, 405 LEXINGTON AVE., NEW YORK 17, N.Y.

MANUFACTURERS : E. K. COLE LIMITED · ELECTRONICS SALES · 5 VIGO STREET, LONDON, W.1, ENGLAND

There's a difference in Marion "regular" Design

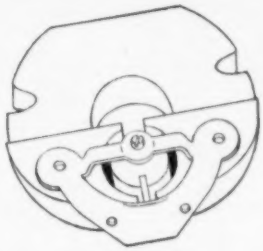
MARION *"regulars"*

In addition to being the largest producer of Ruggedized electrical indicating instruments, Marion has served industry for many years with a line of unsealed instruments for commercial applications. These instruments (Marion "Regulars") have been refined through the years and today serve the "blue chips" of industry in the most critical operations.

The design of these instruments has stayed abreast of new materials and the latest in manufacturing methods. At the same time they have retained the basic simplicity of Marion functional design. This, combined with an efficient, cost-conscious manufacturing organization, affords finer instruments at lower cost.

Marion "Regulars" are selected by the world's most discriminating manufacturers of the finest electronic and electrical equipment as a basic major component of their finest products.

Marion Electrical Instrument Company
414 Canal Street, Manchester, N. H., U. S. A.



ITS *magnetic* SYSTEM

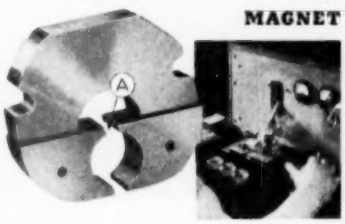
Of the various elements that make up an electrical instrument, perhaps the most important is its magnetic system. The ***strength, uniformity*** and ***stability*** of the magnetic field determine the degree of accuracy and reliability of the instrument. Here is how Marion design provides a magnetic structure of great strength, uniformity and stability, and at the same time keeps weight and cost at a minimum:

MAGNET

All Marion magnets are large, well-aged, precisely ground Alnico II or Alnico V, carefully checked for magnetic uniformity and maximum stable energy.

POLE PIECES

All Marion instruments use sintered and annealed high-permeability, *full* soft-iron pole pieces, of the type employed in the *finest* of laboratory instruments.



MAGNET ASSEMBLY

The pole pieces are permanently fastened to the magnet by induction soldering. Spring loaded fixtures force excess solder out of the seams, leaving a thin film of great bond strength and low magnetic loss. Final separation (A) of pole pieces is done *after* soldering operation, holding gap concentricity to better than .001".

CORE

All Marion "Regulars" use closely machined soft-iron cores which are precisely oriented in the air gap by the instrument frame. (They are not jig located).

These magnetic systems represent a simple, honest means of providing uniform stable magnetic fields for Marion Indicating Instruments. They *never* include laminations, intricate magnetic stampings or uncertain mechanical assembly of the components of the magnetic system.

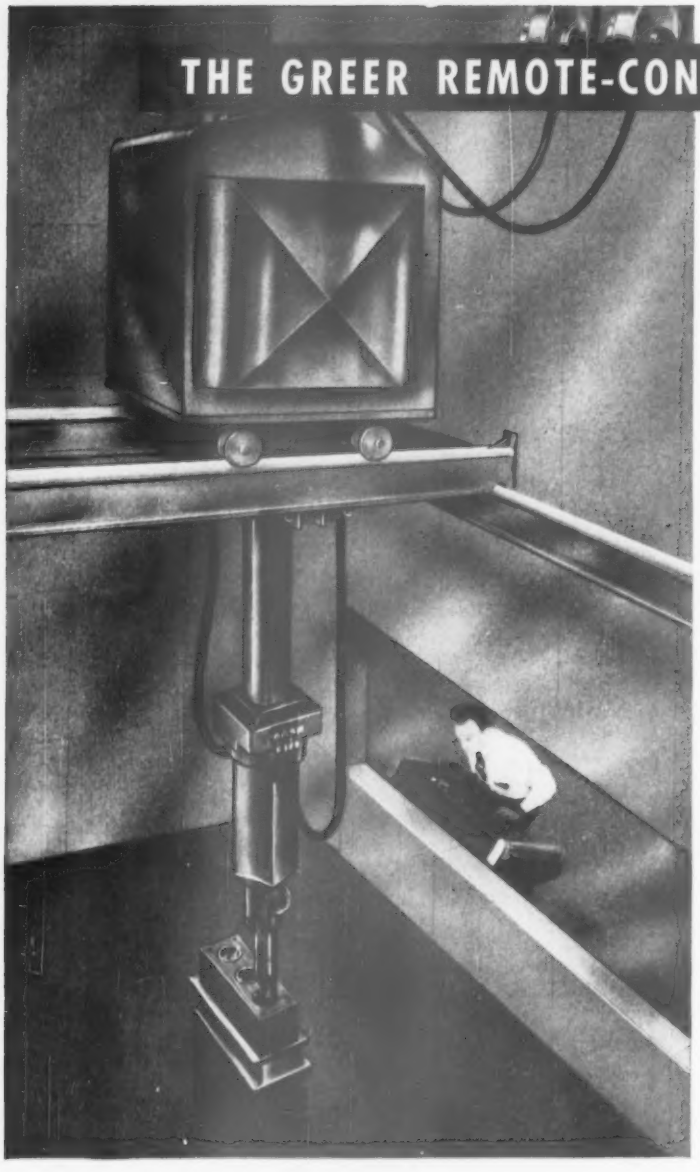
Reg. U.S. Pat. Off.

marion meters

MANUFACTURERS OF RUGGEDIZED AND "REGULAR" METERS AND RELATED PRODUCTS

Want more information? Use post card on last page.

THE GREER REMOTE-CONTROL MANIPULATOR



Rivaling the versatility of a human hand, Greer's new manipulator permits a man to handle dangerous materials by pushing buttons!

The assignment wasn't easy. Greer engineers knew the complex mechanics involved in human hands. The simple act of picking up a pencil, for example, may encompass half-a-dozen distinct and separate motions. But today – after years of patient research and development – Greer is proud to present the proved solution – the Greer Bridge Hydraulic Manipulator.

Providing the operator with complete protection and unimpeded view, this manipulator is ideal for such applications as handling radioactive and highly toxic materials, dangerous chemicals, and others.

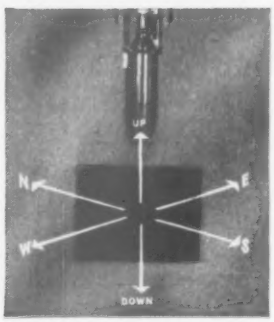
It is a product of Greer Research & Development, a division accustomed to dealing with such out-of-ordinary problems. This department maintains a staff of expert engineers at your disposal; please feel free to call on us at any time. There is no cost or obligation.

GREER
RESEARCH & DEVELOPMENT

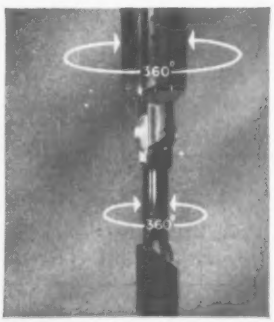
Operater, in photo on left, automatically engages 2½" finger-action tool capable of exerting up to 1500 lbs. Vise and socket tools are shown in tool holder.

A MASTER CONTROL BOARD PINPOINTS OBJECTS, CONTROLS 7 SEPARATE MOTIONS

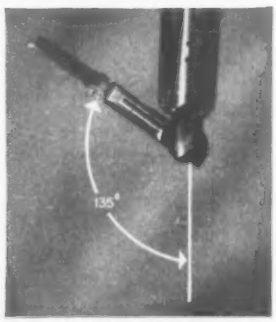
Push buttons control all motions. Rates of motion are determined by foot or hand control. Mobile control panel is mounted on "V" rail and keeps operator opposite work.



Positioning motions are (a) longitudinal, (b) transverse, and (c) vertical. These motions are provided by (a) mobile bridge, (b) trolley, and (c) hydraulic ram.



Rotation of both upper arm and wrist is accomplished through a system of gears and worm gear drive. System is adjusted to prevent interaction between motions.



Elbow action is provided by a 22" forearm rotating in a vertical plane through a 135° arc. This motion can produce 2100 inch-lbs. of torque with 100 lbs. load.

GREER HYDRAULICS INC. · 454 EIGHTEENTH STREET · BROOKLYN 15, NEW YORK

From the world's largest manufacturer of precision potentiometers . . . **Helipot**

come to **Helipot** *for the largest selection of* **multi-turn** *precision potentiometers*

advanced engineering! volume production!

HELIPOT is the organization that originated the helical potentiometer—the device that brought to electronic engineering new horizons of precise control by its greater resolution, higher linearity, mechanical precision, and broad range of resistance values. HELIPOT's policy of constantly working to anticipate the needs of the industry has led to steady advancement in the basic multi-turn principle—and today, HELIPOTS are available in the industry's widest selection of ranges and designs to meet varying requirements.

HELIPOT offers you . . .

▶ **Advanced Engineering.** Through its years of leadership HELIPOT has built an organization unequalled in the industry—with trained engineers, specially-designed equipment, overall facilities to solve *tough* potentiometer problems.

▶ **Volume Production of Special Designs.** HELIPOT not only welcomes tough potentiometer problems, but also has expanded facilities to mass-produce special designs to rigid specifications—at economical cost!

▶ **Versatile Basic Designs.** Most of the basic units shown below can be readily adapted to special requirements—ganged assemblies, servo mountings, single or double shaft extensions, taps spot-welded to a *single* turn of winding at virtually any desired point, and many other individualized features to meet *your particular needs!*

Illustrated below are typical basic models of Multi-Turn Helipots . . .

MODEL A:
A 10-turn unit, approximately 1¾" diameter with 12 to 14 times the resolution of single-turn units of same diameter. Very versatile—low in price—wide range of applications.*

MODEL C:
Similar to Model A, but 3 turns of resistance winding instead of 10.*

MODELS B, D, & E:
Larger-diameter (3 5/16") designs. B has 15 turns—D, 25 turns—E, 40 turns, for applications requiring extreme ranges of adjustment and highest possible resolution.*

ultra-precision

MODELS AN, BN, & CN:
Similar to Models A, B & C in size and performance but feature precision ball-bearings and extra-close tolerances throughout. Have approximately twice the linearity accuracy of equivalent standard Helipots—are ideal servo units.*

miniature

MODELS AJ, AJS, AJSP:
Tiny multi-turn Helipots the diameter of a penny, weight 1 oz. All have 18.5" slide wire for high resolution (1/6550—50 K unit). AJ has threaded bushings, sleeve bearings . . . AJS, servo mountings, sleeve bearings . . . AJSP, servo mountings, ball bearings. Many other features.*

THE Helipot CORPORATION
SOUTH PASADENA 19, CALIFORNIA

See Your nearest Helipot Representative for complete details—or write direct!

Field Offices: Boston (CO. 7-1911), New York (Rockville Center 6-1014), Philadelphia (COlfax 5-3315), Rochester (CU. 7640), Schenectady (DE. 2319), Cleveland (PR. 1552), Detroit (TO. 8-3130), Chicago (PA. 5-1170), St. Louis (SW. 5584), Los Angeles (RY. 1-8345), Seattle (PR. 7515), Dallas (ST. 3338), Ft. Myers, Fla. (FO. 1269-M). In Canada: Cossor, Ltd. Toronto (PR. 1226) and Halifax (4-6481).
Export Agents: Frothaam Co., New York City 18, (BR. 9-1296).

"HELIPOT"—T. M. REG.

New G-E Pocket Chamber Electrometer—

Rapid, accurate reading of dosimeters

Automatic reading and charging of dosimeters is done in one simple operation by depressing lever.

Helping to protect personnel from nuclear radiation is the job of General Electric's new pocket chamber electrometer. Designed specifically for industries and laboratories where a large number of dosimeters must be read each day, the G-E instrument permits fast, highly accurate readings of these pencil-type ionization chambers.

FAST OPERATING—laboratory technician pictured above is comparing the reading of a Victoreen standard pencil with a previous reading. She can accurately read 100 pencils in less than 15 minutes.

VERSATILE, AUTOMATIC—readings can be obtained with either Victoreen standard pencils or Landsverk pencils. Four-inch rectangular meter provides direct indication and extreme readability. Depressing the lever automatically charges pencil and the meter is returned to zero. Further information on this new G-E instrument for health monitoring is given in Bulletin GEC-923.

An illustrated Bulletin, GEA-5735, on other G-E radiation instruments is available upon request. Both of these bulletins or further information may be obtained by contacting your nearest G-E Apparatus Sales Office, or write to General Electric Company, Section 687-114, Schenectady 5, N. Y.

You can put your confidence in—

GENERAL ELECTRIC

NUCLEONICS MARCH, 1953

Jerome D. Luntz, Editor

How Safe is Safe?

THE WORK of the U. S. Atomic Energy Commission affects the public welfare as much as, if not more than, any other government agency—whether the work be bombs or peaceful applications of atomic energy or hazards from AEC plants. As the principal source of information, it is the job of the AEC to keep the public well informed on such matters.

Much has been said about bombs. An official book has even been written on the subject. Peacetime applications have been described by AEC officials in millions of words. But very little has been said about hazards from plants such as nuclear reactors.

At some point in the determination of its information policy, AEC must have asked itself, "How far should we go? Should we tell the public everything permitted by security which is in the public interest?"

Apparently there has been one self-imposed limitation—that stemming from the fear of negative public reaction to (or perhaps misinterpretation of) any talk about man-created environmental radioactivity.

A good example of this was in connection with the decision in 1950 to locate a weapons test site within the continental U. S. Obviously, this was of great public concern. Yet is wasn't until early this year—after erroneous ideas were getting into print—that an explanation of the radioactivity effects of these tests was given. Although waiting three years permitted AEC to back up its statements with considerable data (in an excellent report), a very worthwhile preliminary job could have been done in 1950.

Similarly the time is long past on bringing the public up to date on the hazards of nuclear reactors, which are now dotting almost all parts of the country. This is very much in the public interest because, apart from military security, public safety is the main reason AEC requires tremendous remote reservations for its plants. Almost always, the potential hazards result from the use of fissionable material—in weapon assemblies or reactors—rather than mere handling of large amounts of radioactive materials.

We're pretty familiar with the "hazards" from weapons, but what are the hazards from reactors? Basically, they exist either in normal reactor operation or in the event of a "major disaster." In normal operation, there are two hazards: radiation emanating from the biological shield of the reactor, and radioactivity in the coolant issuing into the atmosphere or the public waters. Although both of these "normal" hazards are not by any means inconsequential, they are pretty well understood and can be protected against without great difficulty.

However, no actual data are available on the consequences of a "major" reactor accident. On the one hand, this is certainly fortunate, but on the other, this lack of data costs money and inconvenience in terms of overprotection.

WHAT IS A "MAJOR" ACCIDENT? In its statement on the release of land in the Wahluke Slope area at Hanford, AEC said:

"The real danger in the operation of Hanford exists in the remote possibility that one or more of the piles may go out of control; if any of these reactors ever go completely out of control, dangerous amounts of radioactivity may be released to the atmosphere. The reactors cannot explode like a bomb, but, under the worst possible conditions, they could produce so much heat that the fuel elements would melt, thus releasing a very dense and highly radioactive cloud—more dangerous than the cloud produced by an atomic bomb explosion."

"The chance of a major accident or disaster occurring in one or more of the Hanford piles is small. There are safety devices that are designed to shut a pile down if it starts to go out of control. Additional safety devices are now being incorporated. But there always remains the chance that all of these safety devices might fail simultaneously or be put out of commission by a natural disaster or by human action."

Was the recent accident in the reactor at Chalk River a "major" one? Presumably it wasn't a "catastrophe" as defined above (although it comes close to being one). But it will for the first time provide valuable data on what happens when a reactor "runs away." Although virtually nothing has been released to the public, both the Canadians and the U. S. will benefit (see page 70).

Another accident in which no public information is available is the one which took place last summer in an experiment with fissionable material at Argonne National Laboratory. This was probably considered a "minor" accident although four people were hospitalized.

WITH A GROWING INTEREST in reactors in industry and in universities, more light must be shed on the whole question of reactor safeguards. What is the state of our knowledge and what is AEC policy? Are there any trends which might result in a change in policy with regard to location of reactors? What about the spheres that Knolls Atomic Power Laboratory and Argonne National Laboratory are building to house their reactors? Is this the key to the future?

The answers to all these questions are not known now. But more than enough information is available to give industry and the public a clearer picture of what is going on.

Organization and Staffing of the Materials Testing Reactor Project

Operation of a reactor and an associated experimental program by a company with no previous atomic energy experience brings up organization and personnel problems. One company solved the problems by relying primarily on its own men

By R. L. DOAN
Manager, Atomic Energy Division, Phillips Petroleum Company
Idaho Falls, Idaho

IN TAKING ON an assignment in the field of atomic energy, the two major initial questions facing a company with no previous experience in the field are: (1) just what is the exact nature of the job; and (2) what training and experience background should be possessed by the men who are to be assigned to the job? In other words, what is the recruiting problem, both internally and externally? Unless one has a reasonably accurate conception of the answers to these questions, much time and money can be lost in enlisting and training the wrong kind of men.

When, in November, 1950, the Phillips Petroleum Company was awarded a contract by the Atomic Energy Commission for operation of the Materials Testing Reactor, then under construction at the National Reactor Testing Station, Arco, Idaho, decisions on the organization of the project and the recruiting of staff had already been reached.

The task of the project seemed, on the surface, rather simple: to operate the plant so that scientists from other AEC contractor organizations could come to the reactor and conduct experimental work.

If one could assume that the operation of a nuclear reactor plant would be comparable to the operation of other more familiar types of plant, then the enlistment of the requisite number of operators plus the necessary supervisory and office personnel should suffice to handle the job. Both the assumption and the conclusion, however, seemed a bit questionable in view of the emphasis placed by AEC on the strength of the research and development organization in selecting a company to operate MTR.

It was decided that the main reliance for the technical, supervisory, and administrative personnel would be placed on company sources. The soundness of this philosophy has been amply demonstrated in the work at MTR, where, except for the kind of experience brought to the job by Phillips engineers, plant difficulties that were solved relatively quickly could easily have prolonged the start-up period several months beyond the two months actually required to get the reactor up to full design power after criticality was first reached.

The recruiting and training program was directed toward fulfilling the responsibilities listed on the next page. For those activities having to do specifically with the unfamiliar field of atomic energy, it was necessary to enlist the training facilities of the Oak Ridge National Laboratory and, to a lesser extent, of the Argonne National Laboratory. Both institutions were very cooperative and helpful in setting up adequate training programs for Phillips personnel. The training period at these places lasted approximately five months.

Organization

The Phillips atomic energy division is organized along the following lines.

Administration. This is handled by a manager, an assistant manager, and a

NEUTRON COUNTING on south face of MTR before it went critical

CONTROL ROOM of MTR just after criticality was reached

Activities That Require Personnel

1. Round-the-clock operation of the reactor and supporting plant facilities
2. Limited maintenance of plant equipment
3. Theoretical and experimental investigations of reactor behavior under varying operational conditions
4. Laboratory services associated with operation of the reactor and conduct of the over-all experimental program
5. Engineering services (including design and drafting) associated with plant operation and the experimental program
6. Technical liaison services in the planning and conduct of the sponsored experimental program
7. Development work on nuclear measuring equipment required in reactor or laboratory investigations
8. Independent experimental investigations approved by AEC for conduct by MTR technical personnel
9. Health physics activities to assure safe operation of the reactor and associated experimental program in respect to normal radiation hazards
10. Special services related to accountability of fissionable materials, receipt and dispatch of special materials, library, preparation and distribution of classified documents, etc.
11. Industrial relations activities associated with recruiting, employee relations, job evaluation, training programs, etc.
12. Financial—disbursement, accounting, reimbursement of government funds
13. Internal audit—budget analysis, preparation, and control
14. Security activities

plant engineer. All three are long-time employees of Phillips with an average of 18 years of service. The manager was formerly research director of the company, the assistant manager formerly superintendent of operations for Phillips Chemical Company, and the plant engineer formerly construction liaison engineer for the natural-gasoline department.

Operations branch. Five full shifts of operation personnel (approximately 14 men to each shift) are provided to maintain continuous operation of the reactor and its supporting facilities and experimental equipment. About one-third of these are technically trained, some as electrical, chemical, or instrument engineers, others as physicists or chemists.

The superintendent of operations was formerly the assistant superintendent of the Philtex Experiment Station in Borger, Texas, and has 14 years of experience with Phillips. The assistant superintendent of operations was formerly a shift supervisor at the Oak Ridge National Laboratory and has had 10 years of experience in the atomic energy field.

The five shift supervisors all came from the research and development department of Phillips and have an average of 10 years of service. Two are physicists, two are chemical engineers, one an electrical engineer. The five shift foremen are all chemical engineers with an average of 5 years of previous experience in operating departments of the company.

The shift personnel in the reactor control room were, with a few exceptions, recruited outside the company and trained on the job. All are college graduates with degrees in physics or engineering. This is likewise true of the 10 junior engineers (2 per shift) who serve as technical assistants on the various experimental setups around the reactor.

To man the reactor supporting facilities (steam plant, water-treating equipment, process-water building, fan house, monitoring devices, storage tanks, etc.), four operators and four operator helpers are provided for each shift. These are hourly-rated personnel trained on the job for their particular duties.

Continuous maintenance of the electronics circuitry directly associated with the reactor control is performed by hourly-rated technicians under the

supervision of an electronics instrument engineer with 11 years of experience in this field.

Specialized operations-branch personnel utilized in addition to the foregoing are: (1) operations coordinator, whose job it is to bring together in one picture all of the things that need to be scheduled during the course of reactor operations and shut-down periods to avoid costly errors and prolonged down-time; (2) personnel coordinator, who keeps the personnel time records, arranges for sick relief, vacation relief, etc; (3) water chemist, who checks the quality of the plant water and specifies any variations in treatment that may be required from time to time.

SPECTATORS in control room as MTR reached criticality, March 31, 1952

Technical branch. The principal role of the technical branch personnel is in support of reactor operations and the sponsored experimental program, although a certain amount of independent research is also carried out on projects approved by AEC.

This work is under the general supervision of a technical director, who was formerly an assistant director of the Phillips research division with 14 years of prior company service, and an assistant technical director recruited from the Argonne National Laboratory, with a total of 10 years prior service in nuclear reactor engineering at the University of Chicago Metallurgical Laboratory, Oak Ridge National Laboratory, and Argonne.

The activities of the technical branch fall into four major categories: (1) theoretical and computational, (2) experimental nuclear and reactor physics, (3) instrument development, and (4) metallurgical and chemical. Technical personnel to staff the various groups were recruited about equally from Phillips and from outside sources. Three of the four section supervisors have from 8 to 10 years service with the company. The fourth came from Los Alamos Scientific Laboratory and has had a total of 10 years of experience in the field of nuclear physics.

Maintenance and engineering services. Although the major responsibility for maintenance work in the various plants at the Reactor Testing Station rests with the National Industrial Maintenance Co. (a subsidiary of Morrison-Knudsen Construction Co.), a limited amount of general and specialized maintenance at MTR is carried out by Phillips personnel. The superintendent of maintenance came from the Oak Ridge National Laboratory where he previously had supervisory charge of the mechanical design and construction of MTR.

Three of the five supervisors in the maintenance branch were drawn from company sources, all of them having in excess of 12 years of service. One was recruited locally. The chief engineer in charge of design and drafting came from ORNL with several years of experience in similar work there, much of it in connection with the design and construction of MTR.

Program coordination. The experimental irradiation program at MTR originates in 10 to 15 different AEC contractor laboratories, each of which is interested in obtaining some specific type of information that can only be developed by the use of a high-flux reactor. Many of the experiments require elaborate equipment which is fabricated by the sponsor and sent to MTR for insertion in the reactor.

All of these irradiations must be engineered to meet some rather severe operating requirements and must be scheduled carefully to insure that the over-all program goes forward smoothly, with a minimum of interference between the various irradiations. It is the function of the MTR program coordination group to work closely with technical representatives of the sponsoring laboratories in the planning and execution of the experiments.

The program coordination group consists of a program coordinator and several project engineers. At the time an experimental project is approved by the MTR policy board* for scheduling in the reactor, a project engineer is appointed to confer with the sponsor and develop all relevant technical information for local planning purposes. His assignment as liaison engineer continues until the job is completed, and includes engineering the installation of the equipment and whatever additions or alterations in local facilities may be necessary.

The MTR program coordinator had many years of technical experience in the petroleum industry before coming to Phillips via the Fairchild NEPA Project at Oak Ridge. Four of the six project engineers have had 5 to 10 years of engineering experience with the company. The other two had similar experience elsewhere before coming with Phillips; one of them was a shift supervisor at ORNL for several years.

Health physics. The health physics program is supervised on a round-the-clock basis by a group of eight employees headed by a former safety supervisor of the Phillips research and development department. The chief health physicist came from the Phillips research laboratory. Of the others, two were obtained from the ORNL-Vanderbilt University Health Physics School, one from the Oak Ridge Institute of Nuclear Studies, and three were recruited locally.

* Approval of the Atomic Energy Commission's MTR policy board, in Washington, is a prerequisite to scheduling any irradiation in MTR.

Industrial relations. The responsibilities of the industrial relations branch include recruiting, personnel records, job evaluation, military service deferment requests, employee activities, physical examinations, public relations, security, and plant safety.

The top supervisor of these activities is a former member of the Phillips employee relations department. There are six staff members, four of whom were recruited locally. The remaining two were transferred from other departments of the company.

Accounting. The functions of the finance branch include the disbursement of funds, maintenance of suitable accounting records, and preparation of reimbursement claims, all in accordance with government regulations.

Until recently, the chief accountant was a senior employee of the Phillips comptrollers department. The present incumbent was formerly chief accountant for the AEC Idaho Operations Office. The assistant chief accountant came from the Phillips comptrollers office with six years of prior accounting experience. The remaining staff members were recruited locally.

Special services. The functions of accountability for fissionable materials, document control, library, special materials records, and receiving and shipping of experimental materials, are all handled by a special services group under the supervision of an engineer with six years of prior experience in one of the operating departments of the company.

Operational Procedure

Initial policy approval of specific proposals for experimental irradiations resides with the AEC division of reactor development in Washington, acting on recommendations of the MTR policy board made up of representatives of all major AEC divisions.

After the necessary approvals have been granted in Washington, the proposals come to Phillips for detailed technical consideration, which usually involves consultation with representatives of the sponsoring laboratory. If, on the basis of such study, the proposal appears feasible, and there is suitable space in the reactor to carry out the work, it is accepted for inclusion in the scheduled experimental program.

The general philosophy governing sponsored experimental work is that the sponsoring laboratory fabricates the required experimental equipment and ships it to MTR where it is installed in the reactor by Phillips personnel under the guidance of technical representatives of the sponsor. Operation of the equipment for the purpose of obtaining in-reactor observational data may be done by either sponsor representatives or Phillips personnel, but in either case is under the jurisdiction of Phillips supervisors.

Maximum flexibility and freedom is permitted visiting technical personnel, consistent with safe and orderly operation of the plant, which is Phillips' responsibility.

Sponsors of Work at MTR

Argonne National Laboratory
Oak Ridge National Laboratory
Brookhaven National Laboratory
General Electric Company
Westinghouse Electric Corporation
North American Aviation, Inc.
University of California Radiation Laboratory
Los Alamos Scientific Laboratory
California Research and Development Company
California Research Corporation
Monsanto Chemical Company
Tracerlab, Inc.

At any reactor where there is a heavy volume of experimental traffic, it is necessary to have the work well planned in order to avoid costly loss of time and possible damage to the reactor. This is particularly important at MTR for a number of reasons, most of which are classified at the present time.

To assure that the various problems associated with the operation of the plant and its associated experimental program receive the careful attention of responsible supervisors prior to the beginning of any project, four major committees have been set up with the responsibility of reviewing all proposals falling within their jurisdiction and making recommendations for the approval of the project manager. These committees are as follows.

Operating committee. This committee is under the chairmanship of the assistant project manager and passes on all proposals for plant alterations or additions, space assignments, and purchase of supplies and equipment in excess of $500.

Program committee. Under the chairmanship of the technical director, this committee reviews and approves, from the viewpoint of technical feasibility, all proposals for experimental work in and around the reactor. The usual procedure is for the project engineer to develop all of the relevant technical information in connection with a proposal for experimental work and to present this information to the program committee for consideration. A technical representative of the sponsoring laboratory may or may not be present at such meetings. The committee may either approve the proposal, subject to later review of some of the specific details, or may request additional information to be developed either by MTR personnel or in the sponsoring laboratory.

Safeguard committee. The safety of MTR is a continuing Phillips responsibility since many things can happen, during the course of extended operations with a wide variety of experimental set-ups, to affect the safety and welfare of the reactor.

It is the responsibility of the safeguard committee to study the changes that may be occurring in the physical behavior of the reactor over a period of time as a result of operations under the experimental program, to pass upon proposals for experimental work that may affect the safety of the reactor, to review and approve any proposed changes in operating procedure or equipment, and to initiate such experimental work on the reactor as may be deemed necessary to answer any questions that arise.

Radiation protection committee. This committee concerns itself specifically with forward planning to prevent the spread of radioactive contamination into working areas and to avoid the development of excessive radiation hazards in the conduct of experimental work around the reactor. Basically, the responsibility for safe working conditions resides with the supervisors in charge of the work, as does also the responsibility for preventing the spread of contamination into areas where it might affect laboratory instruments. However, advice and recommendations from the radiation protection committee have proved to be beneficial in advance planning of the experimental activity.—END

The Half-Lives of Several Radioisotopes

These new determinations of the half-lives of eleven isotopes were made with an electroscope and seem to be more accurate than those now appearing in the literature

By E. E. LOCKETT and R. H. THOMAS
Atomic Energy Research Establishment, Harwell, England

THE RADIOACTIVE HALF-LIVES of Au^{198}, Bi^{210}, Co^{60}, I^{131}, In^{116}, Mg^{27}, Mn^{56}, Na^{24}, P^{32}, Tl^{204}, and Eu^{152} have been determined using a Type TQQ beta electroscope. Most of these isotopes are commonly used for absolute beta standardizations, or as neutron detectors. The remainder have been of interest in other AERE work at Harwell.

The TQQ electroscope was developed by H. Carmichael at Chalk River, Canada, and has been described by D. Taylor (*1*). It is an extremely simple and robust instrument. With it, we have been able to measure most of the half-lives quoted with greater accuracies than those given in previously published results.

The electroscope consists essentially of a hemispherical air ionization chamber containing a quartz fiber, sputtered with gold, which is charged before the measurement. The source to be measured is introduced to the center of the chamber on a tray, and the rate of discharge of the electroscope is measured by timing the transit of the fiber's image across a scale in the eyepiece of the instrument.

As the scale is not quite linear, all measurements were made using a fixed portion of the scale. Timing was done using a stopwatch reading to $\frac{1}{10}$ second, and the time of commencement of each measurement was read to the nearest second from a chronometer. The chronometer was checked against GMT at frequent intervals.

The sensitivity of the electroscope was found to vary with ambient temperature and pressure. A radium source was therefore used to standardize all measurements. This source consisted of 100 μc of radium, encased in platinum, firmly mounted on a plate of aluminum made to fit into the source tray. The radium was measured before and after each measurement on a sample, and the ratio of the activities taken. From the measurements on Co^{60}, taken over a period of eight months, we were able to show that the use of the radium reduced the

Sample preparation

GOLD-198

Gold chloride solution prepared by the AERE Isotope Division from irradiated gold metal was evaporated onto an aluminum plate. The residue of hydrated chloroauric acid, $HAuCl_4 \cdot 4H_2O$, was covered with Durofix in acetone solution, and dried until the Durofix film had set hard.

BISMUTH-210 (Radium E)

Irradiated bismuth metal of about 99.99% purity was used. The bismuth was mounted on an aluminum plate, and covered with thin aluminum foil to absorb any Po^{210} alpha particles.

COBALT-60

Two different samples of cobalt metal were used; one was a cobalt foil of unknown purity activated about four years ago, and the other was in the form of thin cobalt wire (99.99% pure) activated immediately prior to the determination.

IODINE-131

Sample was in the form of silver iodide deposited on an aluminum plate, covered with Durofix solution, and dried.

INDIUM-116

"Specpure" indium oxide was irradiated and mounted on an aluminum foil.

Measurement of half-life	Half-life	Remarks
Decay of the specimen was followed for 10 days. Value obtained was 2.697 ± 0.001 days. With allowance for possible systematic errors, this becomes:	**2.697 ± 0.003 days**	Value is in good agreement with two of three other published values: Saxon and Heller (*2*) 2.69 ± 0.02 days Silver (*2*) 2.69 ± 0.01 days Sinclair and Holloway (*2*) 2.73 ± 0.01 days
Analysis of results indicated the presence of shorter-lived impurities. Measurements were made covering a period of 33 days, and results for the first 7 days were discarded. After this time, the contribution from the impurities was negligible. Value obtained was 4.989 ± 0.008 days. With allowance for possible systematic errors, this becomes:	**4.989 ± 0.013 days**	Value is in agreement with that of Begemann and Houtermans (*3*), who obtained 5.02 ± 0.02, and almost in agreement with that of Hole (*2*), whose value was 5.15 ± 0.1 days. Other values on which no errors are quoted are 4.85 and 5 days given by Seigbahn and Slätis (*2*) and the International Radium Standard Commission in 1931 (*2*), respectively.
Measurements were made for 8 months and the values obtained were: Cobalt foil 4.93 ± 0.05 years Cobalt wire 5.00 ± 0.08 years Since the two values are in good agreement, it seems reasonable to suppose that the half-lives measured were not seriously affected by the presence of other radioisotopes. The weighted mean of these two values becomes:	**4.95 ± 0.04 years**	Values obtained by other observers are: Brosi and Ketell (*2*) 5.1 ± 0.1 years. Sinclair and Holloway (*2*) 5.25 ± 0.21 years (error quoted is the "probable error"). Brownell and Maletskos (*2*) 5.26 ± 0.17 years. Tobailem (*4*) 5.27 ± 0.07 years. Livingood and Seaborg (*2*) 5.3 years (no error quoted). Segrè and Weigand (*5*) 5.08 years (no error quoted). The value given at the left is not in agreement with several of those above, but some are open to the objection that either very few observations were made, or that measurements were made over short periods of time. (Measurements are being continued at AERE with the hope of publishing a more accurate value later.)
Decay was followed for 6 half-lives. No 12-day Xe^{131} was detected in the measurement, although small corrections were made for a very-long-lived isotope found present but not identified. Value calculated was 8.058 ± 0.005 days. With allowance for possible systematic errors, this becomes:	**8.06 ± 0.02 days**	Value is in agreement with that of Sinclair and Holloway (*2*), who obtained 8.04 ± 0.04, and that of Livingood and Seaborg (*2*), who obtained 8.0 ± 0.2, but not with those of Sreb (*2*) and Kurie (*2*), whose values were 8.140 ± 0.006 and 8.16 ± 0.04 days, respectively. No details of these last two measurements are given. Further independent measurements of this half-life would appear to be desirable.
Decay was followed for 6 half-lives. Some contribution from long-lived activity was found, amounting to 0.4% of the initial In^{116} activity. This contribution was too great to be accounted for entirely by 48-day In^{114}. After correcting for the long-lived activity, value obtained was 53.91 ± 0.05 min. Allowing for possible systematic errors, this becomes 53.91 ± 0.12. A previous similar measurement by Bobin and Lockett (unpublished), but using indium metal (99.5% pure), yielded a value of 54.02 ± 0.07. These two results have been combined to give a final value of:	**53.99 ± 0.06 min**	Value is in good agreement with those of Graves and Walker (*2*), and Silver (*2*), who obtained values of 54.05 ± 0.16 and 53.93 ± 0.13, respectively, but not with that of Russell and Wattenberg (*2*), whose value was 54.31 ± 0.07 min.

(Continued on next page)

standard error on a single observation by a factor of four, from 1.2% to 0.3%.

Corrections

Two corrections were applied to all measurements, one for background, and one for nonlinearity of response against activity.

The background was due mainly to natural leakage of the instrument, and amounted to only 0.2% for the lowest activities measured.

The nonlinearity of response was attributed to recombination of ions within the chamber, and the corrections to be applied for it were determined empirically by the following method.

Four small activated cobalt foils, and four inactive ones of the same size, were prepared. The active foils were assigned to fixed positions on the electroscope source tray, and were measured separately, and in groups of two, three, and four together. Inactive foils were placed in any of the fixed positions not occupied by active foils, so as to maintain constant the fractional loss in apparent activity due to mutual absorption between foils. Previous measurements on an active foil with and without three inactive foils present had shown that this loss was very small.

From the differences for each group between the measured activity of the group, and the sum of the separate activities of the individual foils, the corrections for recombination were deduced. The magnitude of the correction was found to be approximately proportional to the square of the measured activity. For most of the half-life measurements, the transit time of the fiber was not less than 20 sec, for which time the correction is 1.25%.

In five of the measurements (Bi^{210}, Mg^{27}, I^{131}, In^{116}, and P^{32}), the presence of other radioisotopes was detected. In these cases, the contributions from the other isotopes were determined sufficiently accurately to have an almost negligible effect on the half-life being measured. Except for Mg^{27}, the corrections were small.

Calculation of Half-Lives

The half-lives were calculated by the method of least squares from the logarithms of the corrected activities, and the mean times from a fixed zero of the fiber's transit across the scale. The assumption was made that the standard error on the logarithm remains constant. This condition obviously does not hold when measurements are made over a period covering several half-lives of a particular isotope. Where necessary, therefore, the measurements were split into groups in which the condition was approximately satisfied. The several values of the half-life obtained, and their errors, were then compounded by the usual statistical method. This procedure serves another very useful purpose in that most systematic errors in the measurements, or errors due to the presence of other active isotopes, should be indicated by changes in the deduced values for the half-life.

The standard error on the final half-life determination for each isotope was increased to allow for possible small systematic errors (e.g., incomplete correction by the radium standard, or inaccuracies in the recombination corrections) and, where necessary, for uncertainty in the corrections applied for the presence of other isotopes. For both of these allowances, the additional error was assessed arbitrarily as 0.1%.

Half-Life Measurements

Rough details of each half-life determination are given in the tabulation nearby, and comparison is made with other published values. To avoid a cumbersome list of references, we have given a reference to the National Bureau of Standards publication "Nuclear Data" (*2*) in all cases where the measurement is quoted there. The author's reference can be obtained from that publication.

* * *

The authors are grateful to Mr. D. J. Littler for suggesting this work, and for his interest and advice throughout the measurements. They would also like to express their thanks to the Standardization Section of the Isotope Division at AERE for preparing many of the specimens, and to the Director of AERE for permission to publish this paper.

BIBLIOGRAPHY

1. D. Taylor, "The Measurement of Radio Isotopes," (Methuen & Co., London, 1951)
2. "Nuclear Data," Circular 499 (National Bureau of Standards, U. S. Department of Commerce, Washington, D.C., 1950–51)
3. F. Begemann, F. G. Houtermanns, *Z. Naturforsch.* **7a**, 143 (1952)
4. J. Tobailem, *Compt. Rend.* **233** (22), 1360 (1951)
5. E. Segrè, C. E. Weigand, *Phys. Rev.* **75**, 39 (1949)
6. R. Wilson, G. R. Bishop, *Proc. Phys. Soc. (London)* **63**, 457 (1949); recalculated by J. H. Sreb, *Phys. Rev.* **81**, 469 (1951)
7. "Neutron Cross Sections," AECU-2040 (1952)
8. D. G. Karraker, R. J. Hayden, M. G. Inghram, *Phys. Rev.* **87**, 901 (1952)

Preparation and

Sample preparation

MAGNESIUM-27

Two samples of magnesium metal were irradiated.

MANGANESE-56

"Specpure" manganese metal was irradiated.

SODIUM-24

"Analar" grade sodium carbonate was used, two foils being prepared.

PHOSPHORUS-32

Sample was in the form of meta phosphoric acid, HPO_3, deposited on an aluminum foil, and covered with Durofix.

THALLIUM-204

A specimen of thallous nitrate, $TlNO_3$, was deposited on an aluminum foil and covered with Durofix.

EUROPIUM-152 + 154

It was requested that the "apparent half-life" of a sample of activated europium oxide, Eu_2O_3, which had been used for the standardization of ionization chambers, be measured. The oxide was contained in an aluminum tube of 0.010-inch wall thickness, and the "half-life" was measured under these conditions. No impurities were present in the sample with sufficiently high cross sections to affect the measurement.

Results of Half-Life Determinations (cont'd.)

Measurement of half-life	Half-life	Remarks
Decay was followed for 3½ hours. The electroscope was standardized with an activated cobalt foil. A spectroscopic analysis of the metal showed that it contained 370 ppm of manganese. Due to its high activation cross section and longer half-life, it was found that the manganese contributed about 8% to the initial activity measured, increasing to 99.9% after 2 hours. Further measurements for 1½ hours and a knowledge of the Mn^{56} half-life enabled accurate corrections to be made for the manganese. For the calculation of the Mg^{27} half-life, all the values thus obtained for the magnesium activity were used up to the point where the magnesium contributed only about 25% to the total activity. This gave over 40 observations for each sample, extending over a period of more than 5 half-lives. Values obtained for the two samples were both 9.39 ± 0.01 min. With allowance for possible systematic errors, the mean value becomes:	**9.39 ± 0.03 min**	This measurement was made by K. J. Bobin and E. E. Lockett at Harwell, but has not previously been published. Other published values are: Henderson (*2*) 10.25 ± 0.25 min Eklund and Hole (*2*) 9.6 ± 0.1 min Crittenden (*2*) 10.0 ± 0.1 min
Decay was followed for 4 half-lives. Value obtained was 2.574 ± 0.001 hours. With allowance for possible systematic errors, this becomes:	**2.574 ± 0.003 hours**	Value is in agreement with that of Livingood and Seaborg (*2*) who obtained 2.59 ± 0.02, and does not differ seriously from that of Bishop, Wilson, and Halban (*2*), whose value is 2.586 ± 0.005 hours. Another value of 2.62 hours by Perlman and Friedlander (*2*) quotes no error.
Decay was followed for more than 5 half-lives. The results for the two foils were: 1st foil 15.00 ± 0.03 hours 2d foil 14.97 ± 0.01 hours Weighted mean 14.97 ± 0.01 hours With allowance for possible systematic errors, this becomes:	**14.97 ± 0.02 hours**	Other published values, with most of which this measurement is in agreement, are: Solomon (*2*) 15.04 ± 0.06 hours Sreb (*2*) 15.06 ± 0.04 hours Sinclair and Holloway (*2*) 15.0 ± 0.1 hours Van Voorhis (*2*) 14.8 ± 0.15 hours Cobble and Atleberry (*2*) 15.10 ± 0.04 hours Wilson and Bishop (*6*) 15.0 ± 0.1 hours
Decay was followed for 75 days and the presence of a little 87-day S^{35} was detected and corrected for. Value obtained was 14.50 ± 0.02 days. With allowance for possible systematic errors, this becomes:	**14.50 ± 0.04 days**	A wide range of other values for this half-life have been published. Value at left is almost in agreement with the first two shown below, but not with the others. Sinclair and Holloway (*2*) 14.59 ± 0.03 days Klema and Hanson (*2*) 14.35 ± 0.05 days Bailey (*2*) 14.30 ± 0.03 days Cacciapuoti (*2*) 14.30 ± 0.03 days Mulder, Hoeksema, and Sizoo (*2*) 14.07 days (no error quoted)
Measurement was carried out over 8 months. Value obtained was:	**2.71 ± 0.05 years**	Value is in good agreement with the value of 2.7 years obtained by Voigt (*2*) (error on his measurement not known).
Sample was measured for 13 months, over which period no deviation from exponential decay was detected. Value obtained under these conditions was:	**12.4 ± 0.4 years**	The abundances of Eu^{151} and Eu^{153} in natural europium are approximately the same, but the cross section of Eu^{151} is about 20 times that of Eu^{153} (*7*). In view of this, and the fact that our measurement indicated simple exponential decay, it is almost certain that the half-life shown at the left is that of Eu^{152}. The value is in good agreement with that of Karraker, Hayden, and Inghram (*8*) who obtained 13 ± 2 years for the half-life of Eu^{152}. Hein (*2*) quotes a value of ~7.5 years for a mixture of the two isotopes (no details of his measurement are available).

Facilities for Gamma Irradiation

At Brookhaven National Laboratory, facilities for irradiation work using Co^{60} and Ta^{182} offer researchers a wide range of experimental conditions. Special equipment includes shielding either by lead containers or, in the case of large-scale research, by water in an irradiation pit

By BERNARD MANOWITZ
Nuclear Engineering Department
Brookhaven National Laboratory, Upton, New York

A NUMBER OF research programs have been established to investigate the cold sterilization of foods and drugs and to study the initiation of chemical reactions in a radiation field (*1*). These are examples of the growing interest in the possibilities of commercially exploiting the interaction of nuclear radiation with matter (*2, 3*).

Principles. The principles involved in these studies are simply as follows: Short wavelength radiation interacts with matter to produce ionization. The amount of ionization produced is dependent upon the energy of incident radiation, and the electron density of the absorbing medium. As a result of the ionization, the chemical structure of the absorbing media is excited, chemical bonds are broken, and free radicals are formed. Thus chemical reactions are initiated.

But free radicals can also be formed by high temperatures or catalysts. What then are the peculiar advantages of short wavelength radiation?

1. The intensity of the incident radiation, and thus the rate of initiation of the chemical reaction, is independent of temperature and pressure.

2. The intensity of the incident radiation is highly controllable even at extremes of temperature and pressure.

3. Radiation energy can be applied externally to the reaction vessel, which may be a special advantage in some cases, or internally to the reaction vessel, which may be a special advantage in other cases.

4. Radiation produced by radioisotopes offers one a fairly wide choice in the penetrating powers of the radiation (i.e., soft beta to hard gamma).

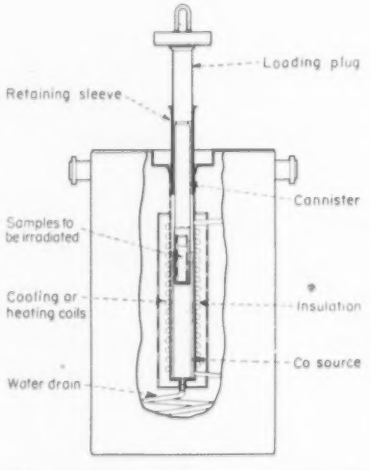


FIG. 1. Lead container for utilization of source

5. The radiation from radioisotopes is mobile and completely independent of other sources of energy.

Of course, there are also disadvantages to the use of radiation for initiating chemical reactions. Chief among these is the fact that the radiation dose required for an appreciable yield for many chemical reactions is extremely high. However, for chain reactions, where radiation must supply only the triggering energy, the dose is reasonable. Another disadvantage, which may be designed against, is the biological hazard.

In the case of sterilization and other biological effects, however, the biological "hazard" may be turned to advantage. The mechanism of the interaction of radiation with biological systems is not yet clear, but the rough rule seems to hold that the more complex the biological system the less radiation dose required to cause an effect (*4*). For very simple biological systems, the dose required is of the same order of magnitude as that required for the initiation of chemical reactions.

Unique application of these principles depends upon the ingenuity of the experimenter.

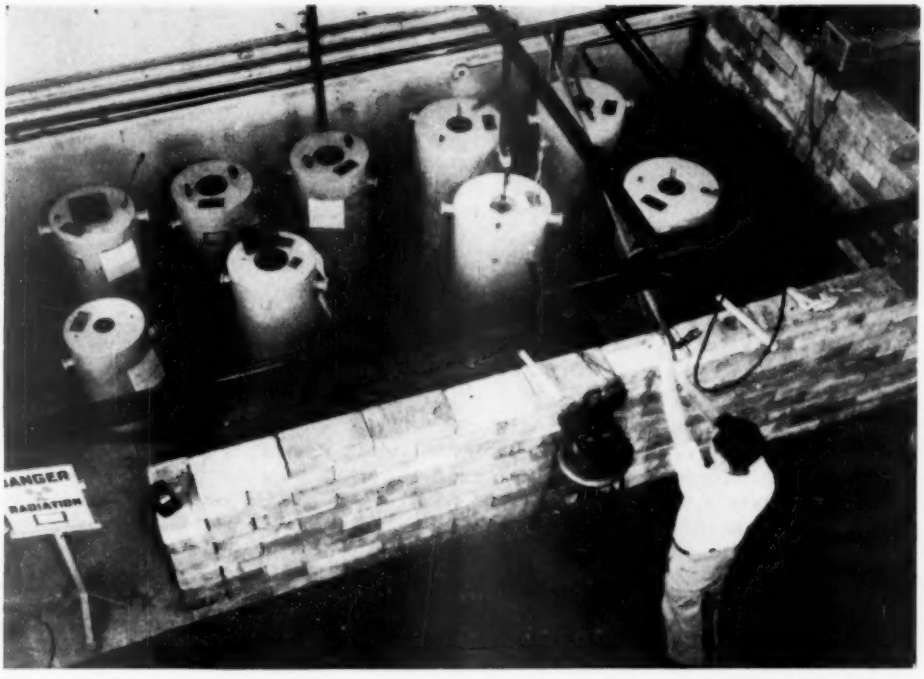


FIG. 2. Gamma-irradiation-research operations area at Brookhaven National Laboratory. The radiation monitor at upper right actuates flashing red light, whenever a plug is removed, to warn passers-by of hazard

Radiation sources. The sources of radiation presently in use at Brookhaven National Laboratory are hollow cylinders of radioactive Co^{60} and Ta^{182} (*5*). The cylinders are sheathed with aluminum before insertion into the nuclear reactor to protect the source element from oxidation during irradiation, and to supply a protective cover.

Sources of various dimensions are now being fabricated. The average over-all dimensions of the tubular sources used thus far are 2.3-in. O.D., 1.7-in. I.D., and 13-in. length.

The intensity of the radiation fields associated with these tubular sources depends upon the length of time the source has been exposed to a neutron flux, and upon the neutron-flux density. Radiation fields up to 300,000 r/hr in the core space of the hollow cylinder have been obtained with Co^{60}, and radiation fields up to 600,000 r/hr have been obtained with Ta^{182}. The radiation level immediately at the outside surface of the hollow cylinders has been found to be about one-quarter to one-half of the core value.

With radiation fields of this magnitude, it is obvious that a first-class personnel-safety hazard exists. With 400 r as a mean lethal dose (*6*), exposure to an unshielded Co^{60} source of the intensity mentioned would result in a lethal effect in < 20 sec, and a damaging effect in < 5 sec.

The general safety criterion that equipment for housing these sources be so designed that personnel are never exposed to a radiation dose greater than 300 mr/week (the accepted AEC maximum permissible dose) is always applied. Specific design criteria depend upon whether the gamma irradiation research is carried out with sources shielded by lead containers, or whether experiments are conducted under water where the water acts as a shield.

Lead Container Shielding

The lead source containers are designed for source loading under water, to be self-draining to avoid the dripping of contaminated water, to serve as storage and shipping containers, and to be accessible for irradiation work.

The newest type lead container to fulfill these requirements is shown in Fig. 1. The container is fabricated of lead encased in stainless steel, weighs 4,000 lb, has a 22-in. diameter, and is 33½ in. high.

After the source is discharged from the reactor into the reactor canal, it is loaded into the lead container under water. First, the lead container, without its loading plug and retaining sleeve, is lowered into the canal. Then the source tube is picked up by an expanding tool at the end of a long rod and inserted into the cavity of the lead shield. The retaining sleeve is fastened into place on top of the source tube to insure that it cannot accidentally be removed from the lead shield. The lead plug is then lowered into place to cover the hole in the shield, and the entire assembly is removed from the canal.

At this point the radiation level at the surface of the lead container rarely exceeds 50 mr/hr. Part of this radiation level is usually due to surface contamination from the slightly radioactive canal water. The lead containers are then washed thoroughly until smear tests indicate that surface contamination is no longer present.

The source and container are then transferred to the relatively isolated operations area shown in Fig. 2. The brick wall serves to restrict access to the experimental area shown. When

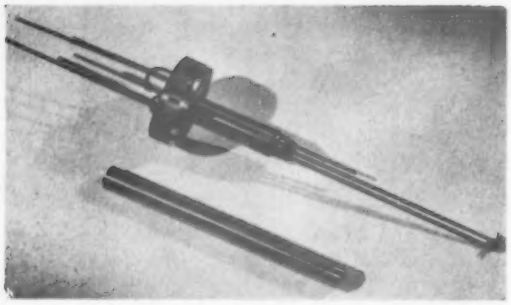


FIG. 3. Plug for flow experiments is part of special equipment available for research

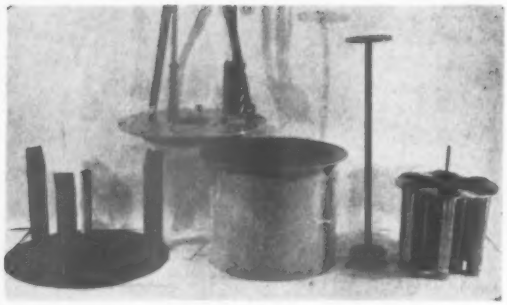


FIG. 4. Gamma irradiation drum for underwater-shielding experiments

the plug is removed from the lead container, scattered radiation from the source inside escapes in a collimated beam. The radiation intensity at the mouth of an average source is about 10 r/hr, but never exceeds 50 mr/hr in the operating area beyond the brick wall. But the beam is appreciable for a height of 10 or 12 feet, so that it is a good idea to house such sources in a high-ceilinged, one-story building.

An aluminum canister which will hold the sample materials to be exposed can be directly connected to the plug. The simple pulley arrangement permits the insertion of canister and plug into the radiation source, while the operator remains at a safe distance to the side of the radiation beam.

A ¼-inch coil wound around the source chamber and insulated from the rest of the lead container (Fig. 1) provides for temperature control within the radiation field. Temperatures from −18 to 70° C have been obtained in this manner. Since the coil is within the radiation field, the arrangement is particularly suitable for making dynamic tests on the stability of heat transfer media in a radiation field.

Special plugs with self-contained access lines, mixers, and pressure-tight canister fittings, have been designed (Fig. 3) so that experiments under controlled atmosphere, controlled pressure, controlled mixing conditions, and/or flow conditions can be performed. Uniform radiation fields can be obtained in the core spaces of the hollow cylinder sources. The effect of radiation intensity can be studied by using several sources.

Water Shielding

The major restriction of research using lead shields is the limited volume of samples exposable. For large-scale experimentation, it is much more efficient to utilize the radiation field on the outside of the source. In this case the radiation field will be nonuniform and will vary as a function of distance from the cylindrical source.

Water to a depth of 10 to 15 ft provides good shielding for large-scale experimentation. Essentially, it is a shield with a hole any place you want one.

One large-scale device designed to be used under water is the gamma irradiation drum shown in Fig. 4. The drum is 29 in. in diameter, 27 in. high, with a 2-in. covering of lead on the top and sides to insure its sinking when empty. The airtight and watertight compartment, 24 × 23½ in., contains 12 canisters, each 17¾ in. long with a 2¾-in. I.D., which can be made to rotate on their own axes. The rotation of these canisters in the radiation field insures a uniform radiation dosage to their contents. If desired, the canisters, together with the associated drive mechanism, can be removed, and four trays, 5 in. deep and 22 in. in diameter, can be installed in their place. The drum also has access ports through which fluid media can be circulated or atmospheres can be controlled.

Brookhaven's gamma irradiation facilities described here will be used primarily for BNL experiments, but will also be available to private industry, to universities, and to other AEC contractors.

The drum was designed to be used under water in the following manner. A guide (seen at the left in Fig. 4) is placed at the bottom of the water pit. In the center of the guide, the source is mounted on a pedestal. Welded into the bottom of the drum is a sealed recess, 4-in. I.D. and 20 in. high. The drum is loaded with material to be irradiated in a convenient location at the surface of the water pit. The drum lid is then sealed into place, and the drum is lowered into the guide. When the drum is in position, the source is situated in the geometric center of the drum. After exposure, the drum is removed from the water pit; the contents can then be safely and conveniently removed. Depending upon the source strength used, it is estimated that radiation fields ranging from 1,000 r/hr to 100,000 r/hr can be obtained with the gamma irradiation drum.

A new water pit which will permit flexible experimentation on a large scale has recently been constructed in an unclassified area at Brookhaven National Laboratory. This water pit, 6 ft wide, 15 ft long, and 10 ft deep, with a 4-ft section at one end dropping to a 14-ft depth, will provide adequate shielding for a large number of sources of various sizes and shapes. The variety of experiments possible will be limited primarily by the size of the water pit.

BIBLIOGRAPHY

1. Current experimental program on fission product utilization, Information Letter No. 1371 (National Canners Association, 1952)
2. Industrial uses of radioactive fission products, report to the U. S. Atomic Energy Commission (Stanford Research Institute, Stanford, Calif., 1951)
3. Industrial utilization of fission products, NUCLEONICS **8**, No. 5, 5 (1951)
4. C. C. Hassett, D. W. Jenkins, Use of fission products in insect control, NUCLEONICS **10**, No. 12, 46 (1952)
5. B. Manowitz, Use of kilocurie radiation sources, NUCLEONICS **9**, No. 2, 10 (1951)
6. Los Alamos Scientific Laboratory, "The Effects of Atomic Weapons" (McGraw-Hill Book Company, Inc., New York; also U. S. Govt. Printing Office, Washington, D. C., 1950)

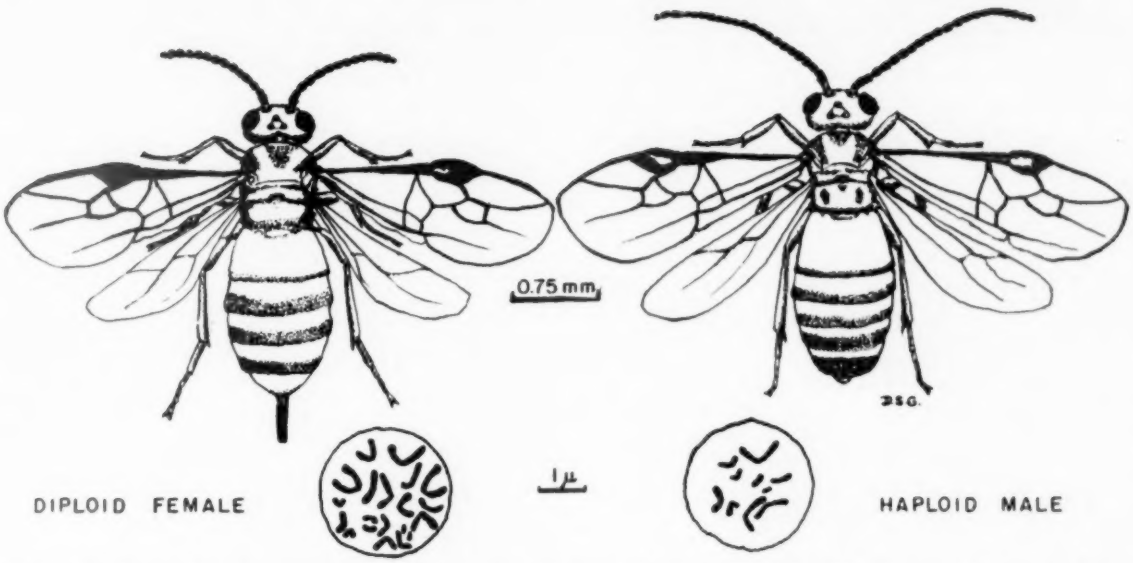


FIG. 1. Dorsal view of the two common types of *Habrobracon* adults and their chromosomes. At left is polar view of an oogonial metaphase showing the 20 chromosomes of a diploid female, at right a spermatogonial showing the 10 chromosomes of a haploid male

The Radiation Tolerance of an Adult Wasp

The effects of radiation and starvation on the adult parasitic wasp Habrobracon have been combined to study lethality and longevity. Both males and females showed an increased life span following irradiation with X-rays

By ROBERT L. SULLIVAN and DANIEL S. GROSCH
Genetics, Biological Division
North Carolina State College
Raleigh, North Carolina

As an adult, the insect appears to be highly radioresistant; indeed the lethal radiation dose for the insect may be more than 100 times that for man or mouse (*1, 2*).

As a result of recent work with a variety of insects irradiated to determine the effectiveness of fission products for insect control in foodstuffs, lumber, etc., Hassett and Jenkins reported that 65,000 roentgens can be considered a fast-killing dose of high-intensity gamma radiation for heavy infestations (*3*).

The insect used in the radiation studies reported here is the parasitic wasp *Habrobracon*. It was chosen because of the opportunity to compare parthenogenetically produced haploid males with biparental types, namely diploid males and diploid females.

Heidenthal (*4*) determined the 100% lethal dose for haploid male *Habrobracon* to be approximately 300,000 r, but the lethal dose on a similar basis for diploid types is unknown. In experiments on the production of androgenetic male offspring, A. R. Whiting (*5, 6*) exposed females, the common diploid type, to as high as

54,000 r without apparent ill effects on the females.

Although haploid males and diploid females are typical of the order *Hymenoptera*, diploid males are exceptional types and the cytogenetic situation appears one of unequalled research possibility in the animal kingdom. Figure 1 shows the two common types of wasps and their chromosomes. The diploid male type, with a duplex set of chromosomes like the female but with external male morphology, can be produced by controlled inbreeding which renders one of the sex-determining alleles homozygous.

The starvation approach was suggested by the finding of Pearl and Parker (*7*) that elimination of feeding reduced variation in the length of life among fruit flies by roughly one half.

Materials and Methods

Haploid males and diploid females of Stock 33 and haploid males, diploid males, and diploid females of Stock 25 were used in our investigation.

Culture vials were checked every twelve hours and newly emerged wasps were removed and stored in clean 70 × 20 mm shell vials in a 30° C incubator. Just prior to treatment, the storage vials were placed momentarily in a bowl of ice water to quiet the wasps and facilitate transfer in groups of five to the gelatin capsules which served as containers during X-ray treatment.

The conditions of irradiation were as follows: The secondary voltage was 182 kv, target distance 2.7 cm, and output intensity 7,210 r per minute. The highest dose used in these experiments was 180,250 r. (Investigation at higher dosages was not feasible with the equipment available. All radiation was done at the Marine Biological Laboratory, Woods Hole, Mass.)

Immediately after treatment, wasps were again transferred to clean vials in groups of five individuals of the same sex and ploidy and stored in a vault where the temperature was maintained at 25 ± 1° C. No food or water was supplied to the wasps.

It is difficult to establish a criterion for immediate lethality where recovery may occur at some time after treatment (*4*). Therefore, periodic subsequent observations seemed indicated. The vials were checked every twelve hours. During the last twelve hours of life, wasps became lethargic and it was necessary to touch them with some small instrument to determine whether they were still alive. A dead wasp was one in which no response was elicited. Dead wasps were removed and time of death and body size were recorded. In these experiments, no correlation was found between body size and longevity. Size variation was held to a minimum by the culture methods used.

Results and Discussion

X-ray doses of less than 108,150 r produced no visible effects. Wasps treated with higher doses, 144,200 r and 180,250 r, became sluggish; all body movement was decreased. However, recovery from this marked change in behavior was relatively rapid. All wasps appeared to have regained normal activity within half an hour. Table 1 presents further results of these experiments by showing dose delivered, number of individuals treated, and mean longevity with its associated standard error.

The mean length of life of irradiated haploid males from Stock 25 was found greater than the control level for all groups and in statistically significant values, except for those treated with 108,150 r. Diploid males were treated with only the highest dose, 180,250 r. The result, not tabulated, is significantly higher than a control value but not significantly different from the result for haploid males treated with the same dose. Specifically, the mean length of life for 47 X-rayed diploid males was 205.02 ± 7.03 hours.

Whereas males treated with increasing doses showed no increase in longevity over that obtained in the 7,210 r experiment, treated females showed an increased life span correlated with the radiation dosage.

From previous experience, it was expected that starved females would live longer than starved males (*8, 9*); the radiation effect, however, was entirely unexpected. That there is a difference due to sex rather than to ploidy is clear from previous starvation experiments uncomplicated by irradiation (*8*). It had thus been demonstrated that diploid males when starved have a typically male life span. Grosch (*9*) showed that females have an effective reserve food supply in the undeveloped eggs in addition to the fat body common to both sexes. Undoubtedly this factor is involved in the present case, where again it is demonstrated that physiological reactions of the sex type outweigh those

TABLE 1—Effects of Various X-ray Dosages Upon Mean Longevity of Wasps

			Haploid males		*Females*	
Stock	*Minutes treatment*	*Dose (roentgens)*	*Number treated*	*Mean longevity (hours)*	*Number treated*	*Mean longevity (hours)*
25	0	0	307	160.14 ± 3.00	44	231.00 ± 9.35
	1	7,210	30	226.80 ± 9.77		
	5	36,050	84	209.43 ± 8.26	13	243.69 ± 16.32
	10	72,100	24	183.50 ± 11.63		
	15	108,150	23	167.48 ± 12.57	14	270.00 ± 13.15
	20	144,200	28	206.57 ± 9.14	17	268.94 ± 19.44
	25	180,250	158	191.77 ± 4.30	56	276.86 ± 10.99
33	0	0	60	189.40 ± 6.88	115	284.24 ± 5.00
	25	180,250	38	217.58 ± 16.17	140	298.54 ± 7.34

TABLE 2—Ingested Radiophosphorus and The Mean Longevity of Wasps

		Haploid males		*Females*	
Experiment number	*μc/cc of mixture fed*	*Number treated*	*Mean longevity (hours)*	*Number treated*	*Mean longevity (hours)*
1	0	57	152.31 ± 3.35	48	165.75 ± 3.74
	100	65	148.80 ± 3.21	44	168.00 ± 3.91
2	0	47	156.00 ± 3.82	36	168.33 ± 4.34
	250	50	157.92 ± 3.68	37	159.89 ± 4.28

FIG. 2. Longitudinal sections of male *Habrobracon;* at left is a frontal section through eyes and stomach, at right a sagittal section showing digestive tract from mouth to anus. *N* = nervous tissue; it marks brain and ganglia. C = crop. S = stomach. *T* = testis. AG = accessory gland of male reproductive system. Heavy black masses are muscle. Broken lines mark boundaries of the hexagonal units which make up the fat body. Not shown are the malpighian tubules that appear at other levels. The female is virtually identical in cross section except that the gonads are two pair of ovarioles

of the chromosome type when it comes to the reaction to starvation.

In the case of Stock 33 treated with only the high dose of 180,250 r, the difference between control and treated individuals was not as great nor as statistically impressive. However, a trend toward longer life of treated individuals of both sexes seems indicated by the differences in mean longevity.

We have no explanation as to why the life span of wasps can be increased by an X-ray treatment. Perhaps if specific abilities of the treated animals could be measured analytically, the efficiency of the treated animals might prove to be impaired and the rate of living found slower for irradiated wasps.

An intimation of the present results is suggested by some incidental observations in other investigations. Davey (*10*) noted an increase in the length of life of the beetle, *Tribolium confusum*, after low doses of X-radiation. P. W. Whiting (*11*) observed under normal culture conditions, that little if any lethal effect is produced on treated *Habrobracon* mothers. Grosch and Sullivan (*12*) reported that internal irradiation from ingested P^{32} had no effect on the longevity of *Habrobracon* females in active parasitization of the host. Another phase of the latter investigation is discussed later.

Radiosensitivity

The accumulating knowledge of the histopathology of vertebrate irradiation (*13*) throws light on the question of why adult insects are radiotolerant. Whereas an adult vertebrate is vulnerable in its dependence upon mitotically active cells and relatively primitive tissue, the adult insect has no obligate replaceable epithelium, no complicated mucous membrane, no hematopoiesis, and no lymphatic system. The insect body surface is nonliving cuticle. As shown in Fig. 2, the adult, internally, is composed chiefly of nerve, muscle, and fat body whose vertebrate counterparts are also notably radioresistant.

Our findings then are consistent with the classic law of Bergonié and Tribondeau which holds that the sensitivity of cells varies inversely with their degree of differentiation (*14*).

The only really vulnerable tissue of an adult insect in which cell division occurs is found in the gonads. Although apparently not a major factor in vitality, this vulnerable gonadic tissue is of the utmost importance in terms of the future generations. For that reason, in spite of failing to shorten life for the individual, it cannot be overemphasized that radiation does irreversible damage to the insect organism and stock. Most of the radiation treatments reported here are well above the permanent sterilization dose, which the present authors place at 5,000 r for the female *Habrobracon* (*15*). Even if a dosage allows eggs to be laid, these would contain deleterious lethal mutations (*4, 11*). A nontechnical summary of radiation's long-term effects on a variety of organisms has been published by Plough (*2*).

Effect of P^{32} Ingestion

In connection with investigations to determine the developmental and genetic effects of ingested radioactive materials,* longevity experiments were made on *Habrobracon* wasps fed radiophosphorus. The wasps were stored at 25 ± 1° C under starvation conditions after a feeding of P^{32}-honey containing an activity above and below that which induces sterility in females.

As seen in Table 2, the insects' life span was not demonstrably affected by the P^{32} decay and beta rays at the level of activity used. These experiments have not been continued because exploration with higher levels of radioactivity was not expedient at the time the investigations were in progress.

* Work performed at North Carolina State College under Atomic Energy Commission Contract AT-(40-1)-1314.

BIBLIOGRAPHY

1. A. M. Brues, G. A. Sacher in "Symposium on Radiobiology—The Basic Aspects of Radiation Effects on Living Systems," J. J. Nickson, ed. (John Wiley & Sons, Inc., New York, 1952)
2. H. H. Plough. Radiation tolerances and genetic effects, NUCLEONICS **10,** No. 8, 16 (1952)
3. C. C. Hassett, D. W. Jenkins. Use of fission products for insect control. NUCLEONICS **10,** No. 12, 42 (1952)
4. G. Heidenthal. The occurrence of X-ray induced dominant lethal mutations in *Habrobracon, Genetics* **30,** 197 (1945)
5. A. R. Whiting. Motherless males from irradiated eggs. *Science* **103,** 219 (1946)
6. A. R. Whiting. Incidence and origin of androgenetic males in *Habrobracon* eggs, *Biol. Bull.* **95,** 354 (1948)
7. R. W. Pearl, S. L. Parker. Experimental studies on the duration of life—X. The duration of life of *Drosophila melanogaster* in the complete absence of food. *Am. Naturalist* **58,** 193 (1924)
8. D. S. Grosch, A. M. Clark. Starvation studies with *Habrobracon* II haploid males, diploid males and females compared in longevity, *Biol. Bull.* **99,** 359 (1950)
9. D. S. Grosch. Starvation studies with the parasitic wasp *Habrobracon, Biol. Bull.* **99,** 65 (1950)
10. W. P. Davey. Prolongation of life of *Tribolium confusum* apparently due to small doses of X-rays, *J. Exptl. Zool.* **28,** 447 (1919)
11. P. W. Whiting. X-rays and parasitic wasps, *J. Heredity* **30,** 269 (1929)
12. D. S. Grosch, R. L. Sullivan. The effect of ingested radiophosphorus on egg production and embryo survival in the wasp *Habrobracon, Biol. Bull.* **102,** 128 (1952)
13. W. Bloom, ed., "Histopathology of Irradiation from External and Internal Sources," National Nuclear Energy Series IV-22I (McGraw-Hill Book Company, Inc., New York, 1948)
14. E. G. Butler in "Biological Effects of Radiation," vol. I, B. M. Duggar, ed., (McGraw-Hill Book Company, Inc., New York, 1936)
15. D. S. Grosch, R. L. Sullivan (in manuscript)

A Simple Pulse-Amplitude Analyzer for Low Counting Rates

Use of an electromechanical system with a self-balancing potentiometric recorder for pulse-height analysis provides simple operation and high accuracy. Such a system, with modification for 20-channel analysis, is described here

By K. KANDIAH
Atomic Energy Research Establishment
Harwell, England

THE POSSIBILITY of using an electromechanical system for analyzing a pulse-amplitude spectrum has been studied by various workers, and the general conclusions would indicate that such systems offer the advantage of extreme simplicity. In particular, the use of a self-balancing potentiometer provides a high degree of accuracy combined with simplicity.

The use of a potentiometric type of recorder for recording individual pulses has also been reported (*1*, *2*). The system to be described here uses a potentiometric type of recorder with modifications to convert it into a 20-channel pulse-amplitude analyzer.

General Principles

The analyzer has been designed to accept pulses from 0.5 to 10 volts. After a pulse is amplified 6 times, a capacitor is charged through a diode to the peak voltage of the amplified pulse. A fraction of the voltage across the capacitor is applied to the input of a high-speed self-balancing potentiometric recorder.

The pen driving mechanism of the recorder is mechanically coupled to a 20-segment switch which defines the 20 channels. Each segment of the switch is connected to a mechanical register, and when the pen comes to rest in any given position corresponding to the voltage on the capacitor, the supply voltage to the registers is switched on for a short period. The pulse is counted in the channel which is selected by the 20-segment switch. The capacitor is discharged during the period when the registers are energized, and the system is then ready to accept another pulse.

One disadvantage of this simple system is that the recorder will continuously follow the voltage across the capacitor, with the result that after each pulse the pen will return to the position corresponding to zero voltage across the capacitor. The time during which the capacitor is left charged to the peak pulse voltage will then have to be longer than the time for the pen to travel from the zero position to the position corresponding to that particular pulse amplitude. If the pulses which are being counted lie in a narrow band in the amplitude spectrum, then the time resolution of the system will be unnecessarily long.

To improve the resolution in these cases, the pen driving mechanism of the recorder is made operative only after the capacitor has been charged to the peak pulse voltage, and it is then made inoperative shortly before the capacitor is discharged. The result is that the pen always remains in the position corresponding to the last pulse it registered. Although the time taken by the pen to travel to full scale is approximately 2 sec, it is possible to obtain an over-all resolution of less than 1 sec for pulses lying in a narrow band.

Amplifier and Charging Unit

The circuit of the analyzer is shown in Fig. 1, and the waveforms at various points are shown in Fig. 2. The input pulse is assumed to have a fast rising edge and a long tail as shown at the top of Fig. 2.

The voltage gain of the amplifier using tubes V_1 and V_{2A} is determined by the ratio of the resistors R_2 and R_3, since this ratio is considerably smaller than the voltage amplification of V_1. The input pulse is differentiated by the time constant of C_1 and R_1 and R_3 in parallel, and the rate of change of the front edge of the pulse is limited by the integrating time constant of the resistor-capacitor combination C_2R_2.

The output pulse at A is as shown in Fig. 2; the output impedance at A is very small. The d-c level at A is very

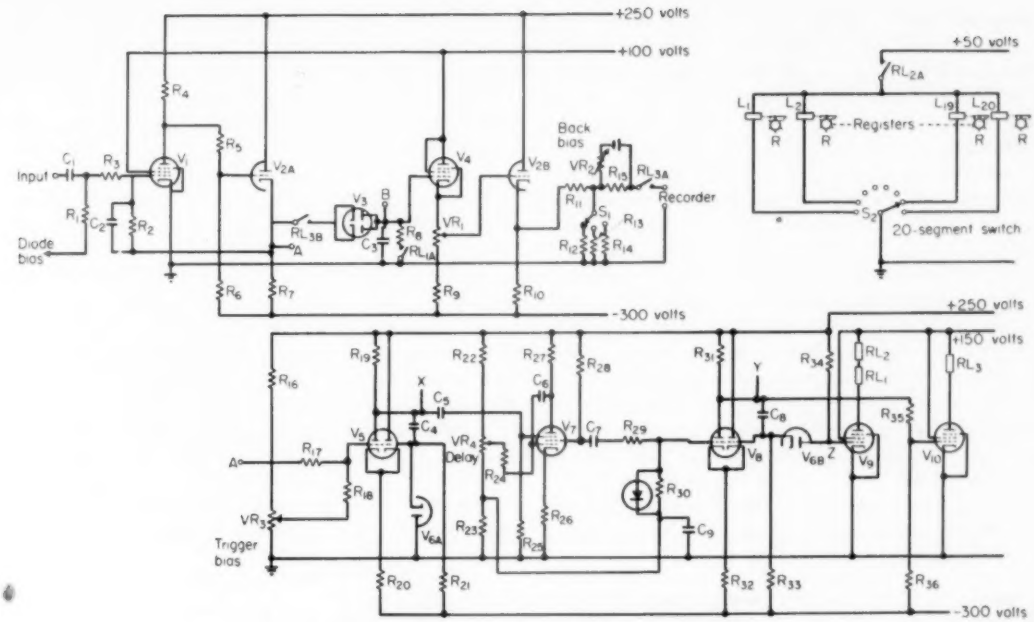


FIG. 1. Circuit of the pulse-height analyzer

stable due to the large amount of d-c feedback, and this level can be controlled by means of the bias applied to the bottom end of R_1. The application of this bias is equivalent to clipping the pulse. The capacitor C_2 is charged through diode V_3 to the peak voltage at A.

The voltage across the capacitor is connected to the cathode follower V_4, which is operated at an anode current of less than 1 ma to reduce the grid current. The total leakage across C_2 is sufficiently low to keep the drop in voltage across the capacitor to less than 1 part in 1,000 in 2 sec.

A further cathode follower, V_{2B}, operating at 5 ma anode current is connected to the cathode of V_4 to obtain a sufficiently low output impedance to operate the recorder. The fraction of the output of V_{2B} which is fed to the recorder is controlled by S_1 which determines the range of pulse amplitude covered, since the recorder has a permanent sensitivity of 10 mv for 20 channels. The three ranges of pulse sizes covered by S_1 correspond to 20, 10, and 5 volts, respectively, referred to the pulse at B. The signal to the recorder is fed in series with a variable voltage obtained from a battery, and this serves as an accurate variable back bias on the pulse.

Trigger Circuits

In the absence of a pulse, contact RL_{3B} is closed and contacts RL_{3A}, RL_{1A}, and RL_{2A} are open. The trigger circuit using tubes V_5 and V_{6A} is operated by the pulse at A in Fig. 1. This circuit determines the minimum amplitude of pulse that is registered, and the threshold is variable by means of VR_3. When this trigger circuit operates, it then triggers the delay circuit using tube V_7, which is set to a time delay slightly greater than the time taken by the pulse at A to reach its peak value.

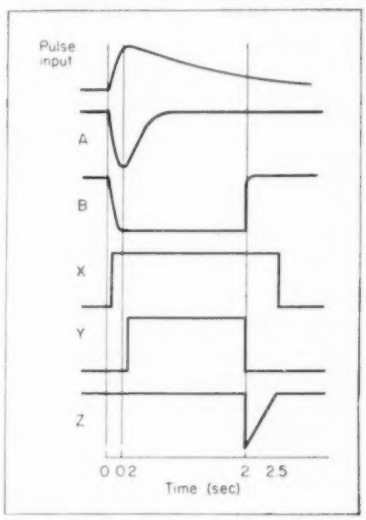


FIG. 2. Waveforms at various points in the analyzer

At the end of this delay period, the third trigger circuit using tubes V_8 and V_{6B} operates for a period of 2 sec. During these 2 sec, tube V_{10}, which is normally cut off, is brought into conduction, and contact RL_{2A} is closed and RL_{2B} is opened by relay RL_3. Thus the pen takes up the position corresponding to the pulse amplitude, and no further pulse can charge C_2 during this period. At the end of the 2 sec, tube V_{10} is cut off, and RL_3 returns to its normal position.

Also at the end of the 2 sec, tube V_9 is cut off for about 0.2 sec, and contacts RL_{1A} and RL_{2A} are closed for this period. Due to the fact that relay RL_1 is slower than relay RL_2, the pen remains in the position corresponding to this pulse, and connection RL_{2A} is broken before C_2 is discharged by RL_1. The contacts of the relay RL_1 are well insulated.

Recorder

The Brown recorder used is of the high-speed self-balancing type with a sensitivity of 10 mv for full scale, and

a pen speed of 2 sec for traversing full scale. At the back of the recorder an extension is fitted to the shaft that carries the drum that drives the pen through a cable.

On this extended shaft, a ball contact is fitted at a radius of 2½ in., and this contact, therefore, travels around a circle and covers approximately 300 degrees for full-scale deflection of the pen. Behind this contact is fitted the insulating plate containing the 20 segments of the channel selector switch, S_2, as shown in the photograph of Fig. 3. The width of the insulation between the segments is about 5% of the width of the segments so that there is a dead space between channels of 5% of the channel width.

The drag on the pen driving mechanism due to the selector switch is negligible. The paper carriage and driving mechanism are not modified, so that a chart record of the pulse amplitude can be obtained when required. This chart serves the useful purpose of making possible identification of any drift or other erratic behavior.

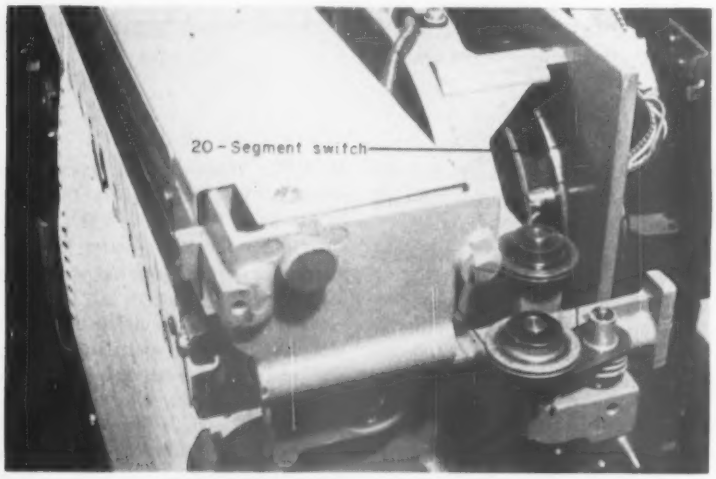


FIG. 3. Pen recorder showing channel selector switch at back

Amplifier; Ionization Chamber

The resolution of the analyzer is normally 2.5 sec, so that the pulse amplifier need not have a resolution of better than 0.1 sec. Further, it is an advantage to use an air-filled ionization chamber in some instances when analyzing alpha-active materials since this dispenses with elaborate sealing and filling of the chamber.

It should be noted that when extremely weak sources are to be analyzed, it is necessary to fill the chamber with radon-free gas to keep the background down to a reasonably low level. When an air-filled chamber is used, it is necessary to collect both positive and negative ions, and the collection time is about 50 msec. Consequently, the amplifier should be capable of handling pulse durations of many hundred milliseconds.

Since a vibrating-reed electrometer can meet most of these requirements and can, at the same time, be designed to have a low noise level, the analyzer has been used with a pulse amplifier that employs a vibrating-reed electrometer.

Vibrating-reed electrometer. The schematic of the connections to the vibrating-reed electrometer (*3*) and ionization chamber is shown in Fig. 4. Negative feedback is applied to the input in the conventional manner through the air spaced capacitor C_{11} which has a capacitance of 10 $\mu\mu$f, but there is no resistor placed across this capacitor. During normal operation, the swith across C_{11} is left open so that C_{11} charges up with the output of the ionization chamber.

The total current from the chamber due to cosmic rays and a 5-Mev alpha source giving 5 cpm raises the mean voltage across the capacitor by 1 volt in an hour. The individual pulses from the chamber produce approximately 2 mv across C_{11}.

The amount of feedback to the lower end of C_{11} from the output of the unit is higher for d-c than for a pulse due to the connection of C_{13} and R_{41}. The pulse feedback is $1/(1 + \alpha)$ times that of d-c, and α is 3,000. The time constant $C_{13}R_{41}$ is 30,000 sec, so that the trailing edge of the pulse output has a time constant of 10 sec. This is sufficiently long to avoid serious overswing of the pulse when it is differentiated with a time constant of 150 msec in the analyzer unit. The output point moves by about 1 volt in 1 hour due to the total charge collected by C_{11}, but each alpha particle produces about 6 volts of pulse at the output.

The unit has been designed to be accurately linear for output voltages up to 30 volts, and it is therefore necessary to short-circuit C_{11} only once in a few hours to avoid nonlinearity.

The battery supplying the voltage to the ionization chamber is filtered by R_{37} and C_{10}. Both C_{10} and the battery are returned through a small resistance, R_{38}, to ground. Calibration pulses can be applied across R_{38} to check the resolution of the system during operation. The calibration pulse takes the form of a fast rising edge which stays up for about 10 sec and then returns slowly to the original level.

Channel Stability

The heaters of all tubes in the analyzer unit are supplied from a stabilized supply, and the drift in channel position over a week is less than half the channel width when the pulses from a 5-Mev alpha source fall in the middle of the highest range.

The pulse size from the vibrating-reed electrometer is also equally stable over long periods since the feedback factor for pulses to C_{11} is more than 100. Because of this large feedback factor, small changes in the capacitance of the ionization chamber have negligible effect on the pulse size from a given source.

Sources of Fluctuations

All pulse amplifiers used with ionization chambers have a measurable amount of random fluctuation at the output. These fluctuations, usually referred to as noise, have two sources of origin in the case of conventional pulse amplifiers. The first of these is thermal agitation in the components associated with the ionization chamber and the circuits in the grid of the first

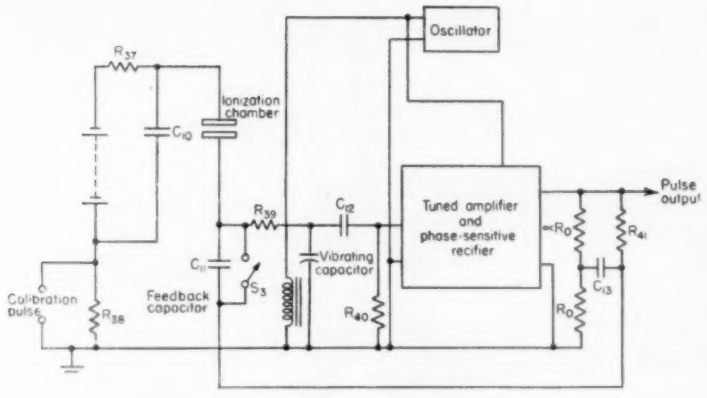


FIG. 4. Connections for using vibrating-reed electrometer as a pulse amplifier

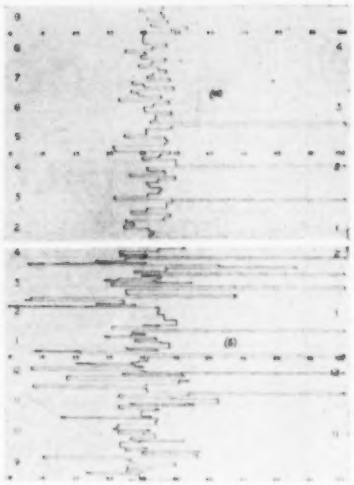


FIG. 5. Typical recorder charts. Top: calibration pulses from pulse generator. Bottom: Record of an actual run

amplifier tube. By suitable choice of component values in relation to the bandwidth of the amplifier, this source of noise can be made negligible.

The second source of noise is the first tube (*4*) in the amplifier, and this is one of the main limiting factors when the amplifier is required to resolve two adjacent peaks in an energy spectrum. The magnitude of this noise is usually referred to in terms of the pulse size at the ionization chamber produced by the collection of a certain number of ion pairs. The root-mean-square noise in the conventional pulse amplifier is equivalent to about 1,000 ion pairs.

In the case of the present equipment there are two other significant sources of noise. The first of these is the noise generated by the vibrating reed due to surface impurities; this is not dependent on the circuit tubes. By careful processing of the electrometer, this source of noise can be made to be of the same order as the noise generated by the first tube, and in some cases it is considerably less than the tube noise.

There is one complicating factor regarding the contributions of the noise due to the first tube and input circuits. The main contribution is the noise centered around the frequency of operation of the reed, which is approximately 300 cycles/sec, but a certain amount of grid-current noise and circuit noise is also generated around the signal frequency, which is about $\frac{1}{10}$ cycle/sec. The noise generated at the frequency of the reed is 10 times more significant in this case than in a conventional pulse amplifier when referred to equivalent ion pairs in the chamber, since the conversion efficiency of the electrometer is 10%.

A further source of noise is the cosmic-ray background in the chamber. In a conventional fast-pulse amplifier, the time constant of differentiation is so short that the individual pulses due to this background are easily resolved and the counting rate is generally so high that the probability of coincidence between the pulse due to one of the particles being measured and a background pulse is very small. In the present equipment, due to the long time constants of the pulse and the low counting rate, the loss of resolution due to the background becomes significant.

Results

Figure 5 shows the appearance of the recorder chart in a typical run with the calibration pulses and with a polonium source. During the straight portions of the recording, the pen remains in the position at which the last pulse occurred.

Figure 6 shows the curves obtained in a typical run with a Po source, the calibration pulse, and on background. A few measurements with a calibration pulse show that the rms noise of the system is equivalent to a little over 3,000 ion pairs in the chamber. The poorer resolution with the Po source is entirely due to the thickness of the source. The background is due to the natural alpha activity of the walls of the chamber after all radon contamination of the air has been removed. This natural activity corresponds to a total mean counting rate of one alpha particle per hour for 10 cm^2 of exposed area of the walls of the chamber. This agrees with the background from other chambers with similar nickel-plated walls.

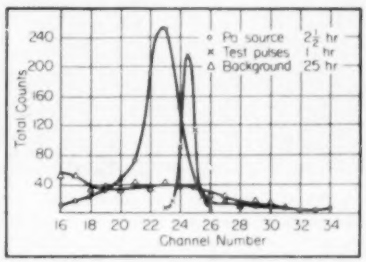


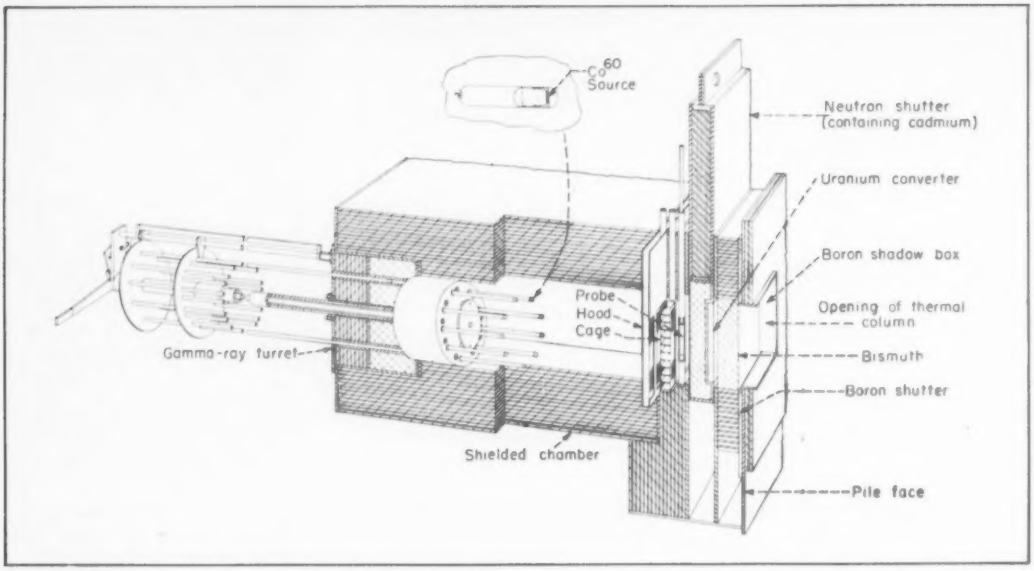
FIG. 6. Total counts in each channel for three sources

* * *

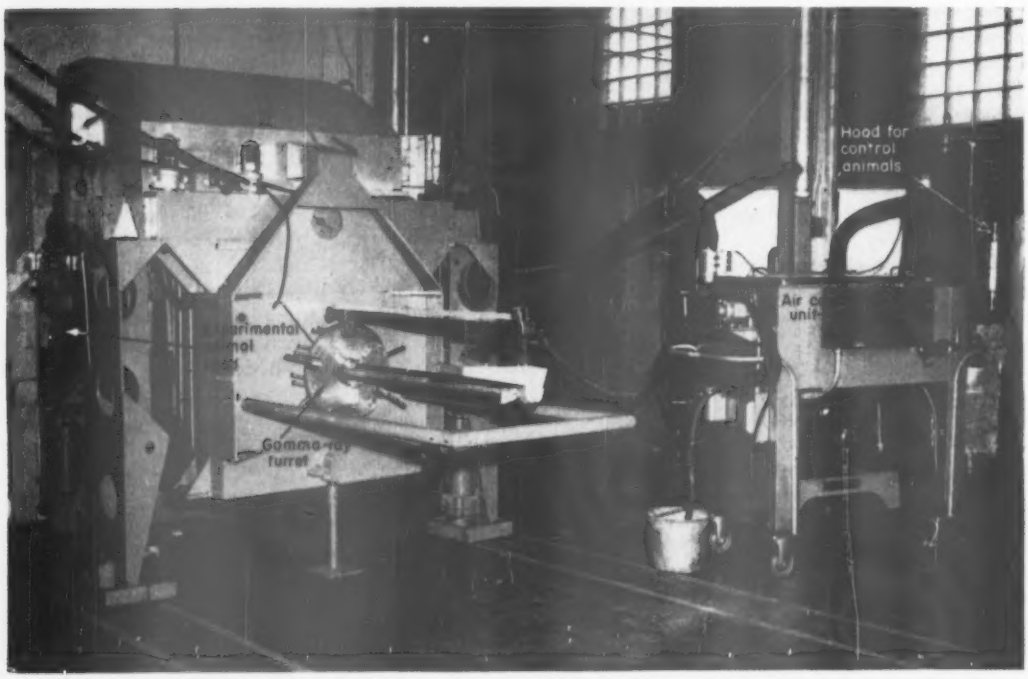
This article is based on a paper presented at the Third Instruments and Measurements Conference, Stockholm, Sweden, Sept. 22, 1952.

BIBLIOGRAPHY

1. W. P. Jesse, H. Forstat, *Phys. Rev.* **73**, 926 (1948)
2. W. P. Jesse, H. Forstat, J. Sadauskis, *Phys. Rev.* **77**, 782 (1950)
3. H. Palevsky, R. K. Swank, R. Grechik, *Rev. Sci. Instr.* **18**, 298 (1947)
4. B. J. Thompson, D. O. North, W. A. Harris, *RCA Rev.* **4**, 269, 441 (1940); **5**, 106, 244 (1940); **5**, 371, 505 (1941); **6**, 114 (1941)



1 RELATION of various parts of chamber is shown by diagrammatic cross section. Radiation chamber is 42 in. square, 60 in. long, weighs 12 tons. Shielded chamber 18 in. square has 12-in.-thick shielding, is attached to second shield 48 in. wide, 55 in. high, 22 in. thick that contains animal cage hood and neutron shutter. Gamma radiation is provided by 60 curies of cobalt-60 in 18 sources in turret. Uranium converter for producing fast neutrons is shown in operating position in front of 16-in.-square opening of thermal column. Gamma rays from thermal column are absorbed by bismuth slab 4 in. thick. Probe drive is not shown



2 IN OPERATION, chamber is supported within ⅛ in. of face of Argonne's CP3' reactor by hydraulically operated legs that also make it possible to raise unit so that trailer can be used to remove it and free thermal column for other work. Both selector disks of gamma-ray turret are pushed in, exposing all 18 sources. Experimental animal hood and hood for control animals are both supplied with 25–30 ft³/min of air with a temperature of 74 ± 4° F and 50% relative humidity by American Instrument Co. climatizer unit. Air velocities through cages do not exceed 25–35 ft/min. Extra plenum chamber on climatizer has damped outlets that supply only amount of air required

Gamma-Neutron Radiation Chamber for Radiobiological Studies

Fast-neutron doses of 150–275 rep can be administered to animals in this unit in 90 minutes. To study additive effects, gamma-ray doses of up to 15 r/min can be administered simultaneously. Dosage can be measured during operation

By HOWARD H. VOGEL, Jr.,* ROLAND A. BLOMGREN,† and NILS J. G. BOHLIN†
Argonne National Laboratory
Chicago, Illinois

THE FACT that gamma rays and fast neutrons are sometimes encountered together makes it important that the question of whether they are additive in producing certain biological effects be investigated. The pursuit of such studies requires apparatus that provides:

1. A wide exposure field so that statistically adequate samples of small animals can be used.
2. A high fast-neutron flux so that a lethal dose can be administered on this field within one to two hours.
3. An arrangement such that gamma rays and neutrons can be administered simultaneously.
4. Precautions in design so that long exposures can be carried out under reproducible climatic and physiological conditions.

All these requirements are met by the radiation chamber described here. Fast-neutron flux is obtained by Zirkle's method (*1*) of using the thermal column of a reactor in conjunction with a sheet of uranium to convert the thermal flux to one of fission neutrons. Pure gamma radiation is obtained from 18 Co^{60} sources. It is possible to expose experimental animals to either type of radiation or to a mixture of them in varying proportions.

The essential parts of this device are the uranium converter and neutron shutter assembly, the gamma-ray turret, animal cage shield and hood, a probe drive for dosimetry, and an air conditioning unit (*2*). All these units are described in the accompanying pictures and captions. In addition, a control panel and trailer are used.

Control panel. To protect personnel during operation, controls for the neutron shutter, dosimetry probe drive, and air conditioning unit are mounted on a panel in a room adjacent to the reactor. Panel lights indicate operation of the units. In addition, interlocks are provided that lock the animal cage in place during exposures and that prevent misoperation of the probe drive.

A motion picture has been prepared recently to illustrate the operation of the radiation chamber (*3*).

Dosimetry

With the CP3′ reactor operating at powers of 150–190 kw, approximately 150–275 rep of fast-neutron dose can be obtained in a 90-min exposure. The fast-neutron flux at the opening of the CP3′ thermal column is approximately 6×10^7 n/cm²/sec. Gamma-ray dose rates from 0.5 to 15 r/min can be obtained by proper selection and positioning of the 18 Co^{60} sources. About 60 curies are used.

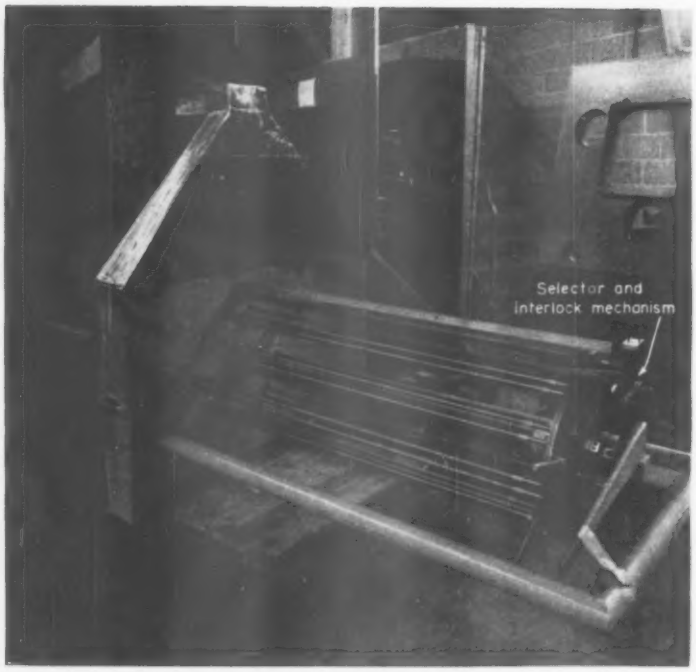
Since the uranium converter and the animal exposure cage are equal in size, the intensity of the neutron beam steadily decreases from the center to the periphery of the animal cage. This variation is also evident in the gamma field from the Co^{60} sources, although to a lesser degree. It is therefore impossible to treat the animals exposed in a single cage as if they have received a uniform dose of radiation. The intensity at each animal position was determined and isodose groups established, three for gamma-radiation experiments and five for fast-neutron and "mixture" experiments, by using the probe unit for dosimetry.

During actual irradiation periods, Victoreen condenser r-chambers are inserted into standard positions in the dosimetry columns of the animal cage.

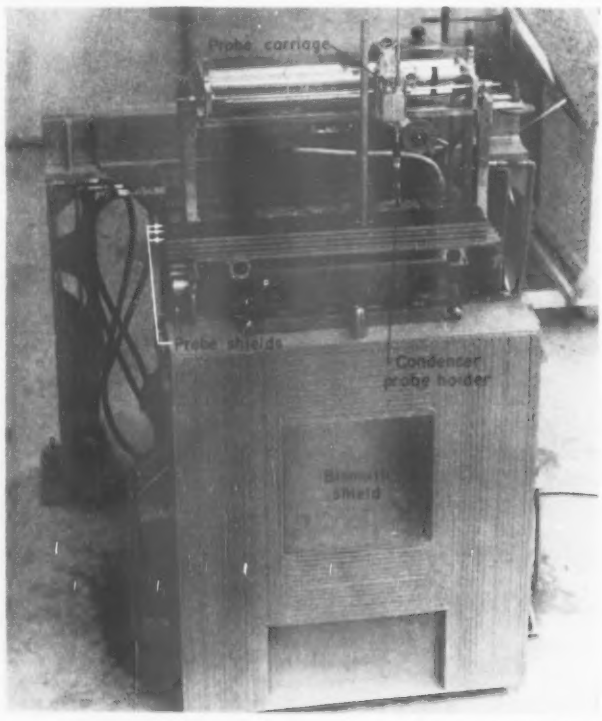
Calibration. With the aid of H. H. Rossi of Columbia University, one of our Victoreen condenser chambers has been calibrated in terms of roentgens-equivalent-physical when exposed to our fast-neutron field. The chamber was calibrated with a tissue-equivalent chamber of 10.1% H composition. Factors have been obtained to relate the response of our other 10 chambers (25, 100, and 250 r) to this calibrated chamber. Thus, after corrections for temperature and barometric pressure, the response of each chamber can be

* Division of Biological and Medical Research.
† Remote Control Engineering Division.

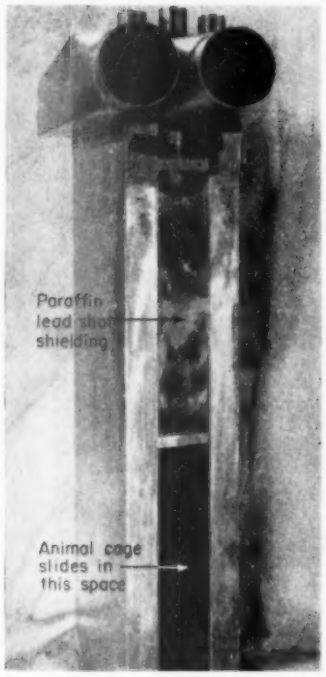
3 **NEUTRON SHUTTER**, shown being installed, is raised and lowered by chain and sprocket driven by a hydraulic transmission powered by 1-hp induction motor. Cam device and limit switches control operation; shutter travels 22 in. in 10 sec. Shutter is 26 in. wide, 56 1/2 in. long, 4 7/8 in. thick, weighs 1 ton. Lower portion holds 16-in.-square, 1-in.-thick natural uranium converter slab with 1/4-in. boron carbide Plexiglass on five sides to absorb slow neutrons. Lead slab 3 1/2 in. thick behind converter absorbs gamma rays. Upper part of shutter contains two 1/32-in.-thick strips of cadmium to stop thermal neutrons from thermal column when the shutter is down. But slow-neutron bombardment of the cadmium caused 5 r/min gamma radiation at animal cage with shutter closed until 1/4-in.-thick boron carbide Plexiglass shutter operated by steel cable attached to neutron shutter (Fig. 1) was added. Boron shutter slides between face of pile and chamber, works in opposite phase to larger neutron shutter. It reduced radiation to 0.1 r/min, but would not have been necessary if boron had been used in place of cadmium originally. Guide pin at top of shield helps position chamber accurately at face of thermal column



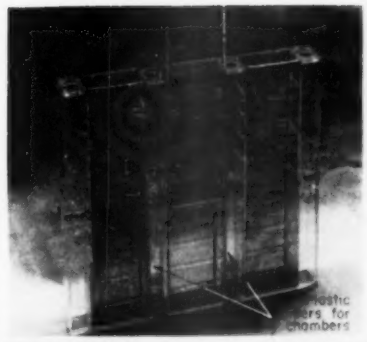
4 **GAMMA-RAY TURRET** is stored on handtruck with added shielding when not in use. Turret consists of 24-in.-square, 17-in.-thick shield with 17 1/2-in.-diameter, 8-in.-thick lead shutter. A 3-in. tube attached to center of shield acts as guide for two source-selector disks and supports meter stick that shows position of sources. Nine stainless-steel rods 6 ft long are attached to each disk. Cobalt-60 source 1 cm in diameter and 2 mm thick is encased in aluminum can at end of each rod. Handle connected to end of steel rod passing through center tube is used to rotate shutter to shield all sources, or allow either 9 or 18 sources to be used. Interlock prevents operation when turret assembly is not in place in chamber

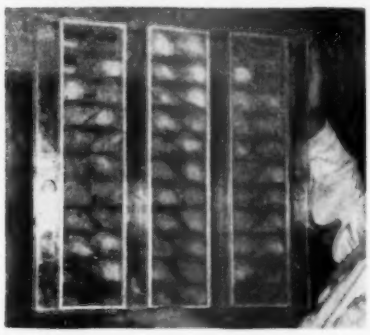


7 **PROBE UNIT** is connected to rate meter and recorder. Entire field of cage can be mapped in five minutes. Bridge structure supports carriage with attached drive mechanism to obtain horizontal travel for carriage and probe shields, vertical travel for dosimetry probe on rod. Trip cams on mechanisms actuate stepping switches on remote control panel, keeping probe moving until position set on remote panel is reached. Probe can be positioned in any of four channels in cage and in corresponding channels on each side of it. Interlocks prevent misoperation, stop probe if dosimeter is in channel. Shield moves with probe, aligning 1 1/8-in. clearance hole with desired channel



5 HOOD for animal cage is permanently installed in chamber. Plenum chambers on each side provide for air flow through cage. Twelve holes through top are provided for dosimeter probe. Space between plenum chambers at top is filled with paraffin and lead shot for shielding. Cage shield 18 in. high, 48 in. long, $2\frac{1}{4}$ in. thick, slides in center of hood, is rolled out for loading cage. In operating position, center of animal cage is about 7 in. from center of uranium converter





6 ANIMAL CAGE is constructed of cemented Plexiglass. Channels for probe and for dosimetry chambers in plastic holders divide cage into three rows of compartments that can be loaded by lifting sliding aluminum screens. In latest cage, compartments are divided by diagonal Lucite strips to form 66 exposure cells, each holding one mouse

corrected to give a dosage measurement in standard units. One of the Victoreen 25-r thimble chambers with a 4-mm plastic cap was calibrated by the National Bureau of Standards for gamma rays of Co^{60} in terms of International Roentgens.

By use of films and a carbon chamber, Dr. Rossi concluded that the gamma-ray contribution to the tissue dose in this neutron field is less than 10% of the dose due to fast neutrons.

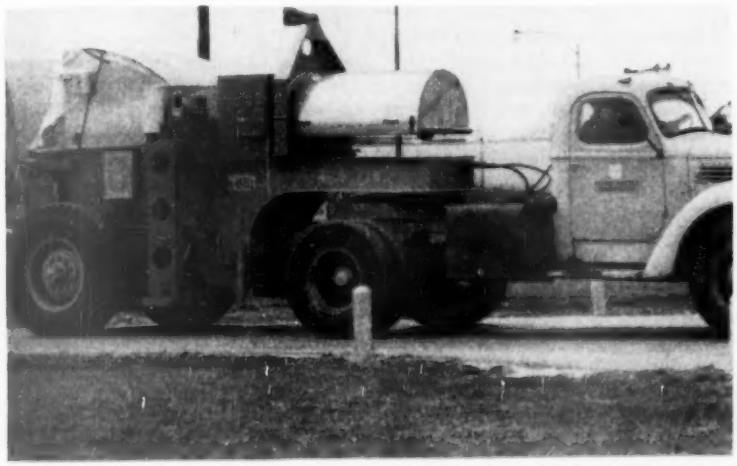
Experimental Plan

This gamma-neutron chamber is now being used to study the problems of additivity of these two forms of radiation on lethality of CF-1 female mice. Complete survival curves are being constructed for these mice after gamma irradiation, fast-neutron irradiation, and mixtures of the two in varying proportions. These experiments are being carried on at several dose rates.

More than 10,000 experimental and control animals are already in the experiment. After a single acute exposure to radiation, the animals are transported in an air-conditioned truck to special animal quarters where they are observed for the length of their lives. Studies are now underway on the effects of these radiations on length of life, tumor incidence, involution of lymphatic organs, fertility, cataract formation, and other pathological and physiological effects. Chronic exposures are also planned for the future.

* * *

The original experimental plan for this radiation chamber was conceived by collaborative efforts between R. E. Zirkle, University of Chicago, and A. M. Brues, ANL. L. D. Marinelli and H. E. Kubitschek, ANL, and H. H. Rossi, Columbia University, helped with problems of dosimetry. Members of the ANL Remote Control Engineering Division, especially R. Miller, R. Wehrle, and L. Haaker, contributed to both design and construction of the facility, while the Central Shops had the laborious task of fabricating and assembling the unit. The experimental plan for use of the apparatus was set up through the cooperative efforts of members of the Neutron Radiobiology group, especially J. W. Clark, C. P. Stroud (deceased), and D. L. Jordan.



8 TRAILER, weighing $1\frac{1}{2}$ tons itself, is used to transport radiation chamber. Bed of trailer is steel beam structure with rollers to allow chamber to slide sideways when being positioned against reactor face. Gamma-ray turret is positioned over yoke of trailer. Trailer uses two 18-ply tires, 13.00 × 24

BIBLIOGRAPHY

1. R. E. Zirkle, J. R. Raper, E. F. Riley, Jr., G. E. Stapleton, CH-2571 (1945)
2. H. H. Vogel, Jr. Abstract of the neutron radiobiology program at Argonne National Laboratory, *Anat. Record* **113**, No. 4, 70 (1952)
3. Motion picture 141.275 (Argonne National Laboratory, Chicago, 1952)

Extending the Efficient Range of G-M Counters

A two-tube cut-off circuit reduces G-M tube deadtime to 1.5 μsec and permits operation up to 20,000 cps with deadtime losses of only a few per cent. Other methods reviewed are too elaborate, or they correct for deadtime without reducing it

By W. C. PORTER
Bartol Research Foundation of The Franklin Institute Swarthmore, Pennsylvania

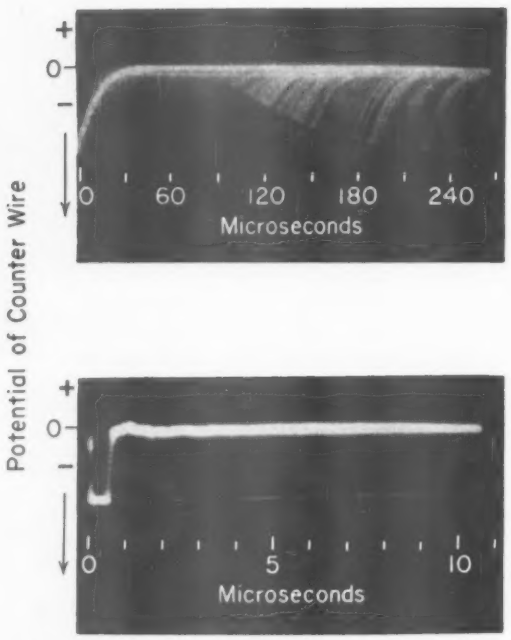


FIG. 1. Oscilloscope sweep triggered by G-M counter. (Top) Stever's method of deadtime presentation under normal operating conditions. (Bottom) With cut-off circuit applied to counter

THE G-M TUBE DEADTIME effect, normally of the order of 10^{-4} sec, has led many investigators to employ more complicated detection instruments.

During the past ten years, numerous methods of reducing deadtime have been developed. In general, the procedures have been either too complicated or have not yielded sufficient improvement to encourage wide application. A "cut-off" circuit has been devised (*1*) which overcomes both of these difficulties and reduces the inoperative time to approximately 1.5 μsec.

To define deadtime and to convey some quantitative insight into its effect on the counting efficiency of a G-M counter, we shall discuss the mechanism of discharge as it is presently understood, and shall review the methods which have been used to achieve improved efficiencies at high counting rates.

Deadtime Discussion

According to the discharge mechanism of G-M counters, first suggested by the work of Ramsey (*2*) and Montgomery and Montgomery (*3*), the active discharge of the tube occurs in about 10^{-6} sec. In many counters, the total transit time of the positive-ion sheath to the cathode is of the order of several hundred microseconds. In general, the voltage pulse initiated by a discharge is characterized by a rapid negative potential change during the period of electron collection, followed by a relatively slow negative continuation induced by the migration of positive ions toward the cathode.

Usually, the *RC* time constant of the external circuit is small compared to the positive-ion collection time. Thus, the central wire reaches a peak negative potential and returns almost to its quiescent voltage long before the ion collection is complete. However, a new discharge does not occur until the positive-ion sheath, which dominates the field around the wire, has migrated enough to allow the field to reach the G-M threshold level.

A new discharge which occurs after the insensitive interval, but before the ions are completely collected, is smaller

in amplitude than one produced when the counter is in its quiescent state because of the reduced field between the wire and the uncollected sheath. The counter response following a discharge is shown in Fig. 1 (top).

Stever's method. Deadtime may be studied with a technique devised by Stever (*4*). A counter discharging at a moderate rate triggers repetitively the sweep of a cathode-ray oscilloscope; the counter output pulses are applied to the vertical-deflection amplifier. The counter dimensions are 6 in. long, 1 in. in diameter, with a 0.003-in.-diameter central wire.

The upper picture of Fig. 1 is a time exposure showing many superimposed sweeps. The vertical descents of the pulses are not visible due to their rapidity. The triggering pulse of each sweep occurs at the extreme left; the pulses farther to the right occur at random times after the sweep-initiating pulses. Each triggering pulse is succeeded by a 100-μsec deadtime period. The randomly occurring pulses following the deadtime interval define an envelope which reaches a constant level at approximately 250 μsec. The increasing size of delayed pulses reflects a dependence of pulse height on the position of the moving positive-ion sheath.

Muehlhause (*5*) has shown that when a counter is discharged within the time required for recovery from a previous pulse, the insensitive time after the secondary pulse is shorter than that following a full sized pulse. The effective deadtime thus depends upon the distribution of time delays between successive discharges.

Correction of constant deadtime. The information gained from a presentation such as Fig. 1 is insufficient to predict the deadtime loss of a counter at arbitrarily high counting rates. Where the deadtime may be considered a constant, a simple expression can be derived for correcting the counting rate of a single counter. If N is the recorded counting rate and N' the rate at which the counter would count if it suffered no deadtime loss, then

$$N' = N/(1 - N\sigma)$$

where σ is the period of time required after a full discharge before the counter is again capable of yielding a pulse large enough to trigger the recording apparatus.

This expression gives N' correct to 1% as long as the probability of an initiating particle entering the counter within the complete recovery time of a previous discharge is less than 0.1. For example, as applied to a typical counter having a deadtime $\sigma = 10^{-4}$ sec and a complete recovery time of 3×10^{-4} sec, the formula would give N' correct to 1% for N up to 300 cps.

To utilize ordinary counters for precise quantitative work at rates higher than a few hundred counts per second, an empirical method of calibration is necessary, using some linear device such as an ionization chamber or a photo-electric cell. Precautions must be taken to avoid statistical uncertainties in the calibrating device.

The effects of deadtime are generally more serious in coincidence arrangements of G-M counters than in the case of single-counter operation. Suppose, for example, each of n identical counters in a coincidence array counts a fraction f of the rays which traverse it. Then the n-fold coincidence efficiency is f^n, which is a smaller value than the individual counter efficiency.

As has been seen in the preceding discussion, the positive ion sheath which remains near the wire after a discharge is the principal factor determining the deadtime of a G-M counter. Consequently, the methods which have been devised to render a counter operable at high rates have been aimed at removing the sheath as rapidly as possible, or limiting the spread of the sheath to a short segment of the wire.

Beaded-Wire Counters

Brodie and Stever (*4*) observed that when beads were placed on a counter wire, the spreading process was limited to a segment of the tube length. With a single bead at the center of the wire, the two halves of the counter could be discharged independently. Apparently little use was made of this observation until Curran and Rae (*6*, *7*) made a further study of the recovery properties of beaded-wire counters, and were able to obtain with a 15-bead counter an effective resolving time of $\sim$10 μsec. Parratt, Hempstead and Jossem (*8*) have reported measurements with beaded counters over the range 1–10^5 cps.

An interesting theoretical analysis of counting losses of long beaded X-ray counters was made by Nonaka (*9*). His calculations show that, for a given percentage loss, a long counter having a wire divided by beads into n equal segments should be capable of counting n times the X-ray intensity which an unbeaded counter of the same length could count. It was assumed that the X-ray beam was directed along the axis of the counter, and that the absorbtion of the beam in the gas was small.

Some of the disadvantages which arise with beaded counters are: (1) difficult construction and duplication; (2) poor plateaus as a result of the perturbing effect of the beads upon the electric field near the wire; and (3) an extremely large number of spurious counts. In fact, Parratt *et al.* (*8*) utilize such counts to render the observed counting rate of a beaded counter more nearly proportional to source strength. In virtue of the fact that the number of spurious counts varies with aging, this latter procedure seems of questionable value.

High-Gain Amplifier

At very high radiation intensities, most of the pulses from a G-M counter fall below the level required to trigger an ordinary recording circuit. It was shown by Trost (*10*) that the integrated pulse current in counter tubes continues to increase far beyond the "choking" region for counting with an ordinary circuit.

Muehlhause and Friedman (*5*) furthered the work of Trost by using a high-gain video amplifier of 0.01-volt sensitivity. Their work indicates that the effective deadtime varies with overvoltage and with counting rate. Their range of deadtimes (at low rates) varied from about 500 μsec, near the Geiger-Müller threshold, to about 150 μsec near the limit of the plateau. With a fixed overvoltage, the effective deadtime varied from 220 μsec, at 100 cps, to nearly 10 μsec at 60,000 cps. Thus, the maximum counting rate of a typical G-M counter may be pushed to 100,000 cps by providing sufficient pulse amplification, but the gain in resolving power up to 10,000 cps is relatively slight.

Circuit Control

Neher and Harper (*11*) first successfully increased the working rate of counters electronically. Their circuit was a simple one. The initial voltage developed by a counter when applied to this circuit resulted in a reduction of

potential to a point below the starting value. For each pulse, this reduction was sustained until the original working potential could be restored without subsequent breakdown. A time in excess of 10^{-4} sec was usually required.

The circuit was intended for non-self-quenching mixtures which in normal use gave inoperative times from 10^{-3} to 10^{-2} sec, and were workable only at very low rates. The limitation for such mixtures is the time required to eliminate all particles capable of releasing electrons from the gas or from the cathode—a period which may be longer than the time required to sweep positive ions to the cathode.

Self-quenching counter. The self-quenching counter greatly extends the possibilities of circuit control of deadtime. In such counters, processes occur which greatly reduce the probability of ejection of electrons from the cathode at the time of arrival of the positive-ion sheath. Furthermore, de-excitation of gas atoms excited to metastable states is greatly accelerated, so that the wire potential may be restored to normal very soon after the start of a discharge without danger of initiating spurious counts.

Since the deadtime in a self-quenching counter is determined solely by the time which the sheath requires to reach the critical radius, Simpson (*12*) reasoned that a reversal of potentials would draw the sheath back to the wire—and in a time considerably less than the normal deadtime. Following this collection, the usual working voltages could be restored. His procedure led to a minimum insensitive time of 2.0×10^{-5} sec, reducing the normal deadtime by a factor of five.

The elaborate circuit used to achieve these large short-time alterations in potential discouraged wide use of the original procedure. However, Simpson's work introduced a basic idea and stimulated other investigators to seek simplification.

Flip-flop circuit. Hodson (*13*) achieved a great simplification of Simpson's procedure when he was able to reverse the sign of counter potentials using a two-tube flip-flop circuit in place of the nine-tube arrangement. He observed an insensitive time of 3.0×10^{-5} sec.

The work of both Simpson and Hodson was dominated by the idea that the reduction in deadtime was due to a rapid collection of positive ions. However, it was becoming increasingly obvious that some of the improvement afforded by the potential-reversing circuits arose from an interruption of the spreading of the discharge along the wire—a real quenching of active ionization. Hodson, in a later private communication to Smith (*14*), suggested that such a quenching must have occurred. Smith estimated that the spreading was limited to about 40% of the length of a 60-cm counter, and referred to further work by Hodson which displayed the same deadtime reduction when the potential across a counter was reduced only 250 volts.

The trend for reducing the deadtime now was to limit the discharge before it had spread the entire length of the wire. Elliot (*15*), using a two-tube multivibrator arrangement, succeeded in limiting the discharge to 25% of the length in a 60-cm tube, and Collinge (*16*) later limited the spreading of the discharge to 5 cm or less in a 30-cm tube. Unfortunately, Collinge's circuit involved a large number of tubes and his minimum deadtime was not under 2.0×10^{-5} sec. Neither of the last two investigators made use of a reversing potential, and both achieved their reduction of insensitive time solely by interrupting the ionizing process.

Fixed deadtime. In another approach to the problem, den Hartog and Muller (*17*) developed an ingenious arrangement which externally fixed the deadtime, setting it at a value in excess of the total collecting time of the ions. Although a counter tube is thus inoperative for a relatively long time, the circuit provides a meter which indicates directly the percentage of sensitive time for each counting rate. Den Hartog and Muller state that corrected rates up to 20,000 cps were successfully handled with this circuit.

In one specific instance, a 12-mm-diameter counter with an active length of 30 cm was used. With an incident radiation of 20,000 cps, the counter was operative for 15% of the time. Thus, only 3,000 cps were actually recorded. While use is not made of the fact to achieve short deadtimes, this circuit also interrupts spreading and confines the active discharge to 4 cm along the counter wire.

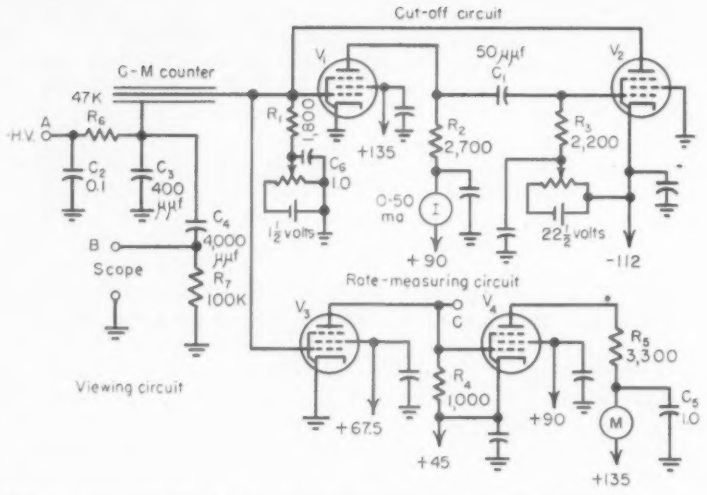


FIG. 2. Two-tube cut-off circuit with rate-measuring circuit for high speeds

Cut-Off Circuit

Ramsey, in 1949 (unpublished), succeeded in confining the discharge to 1 cm of the wire length in a 20-cm tube, and thus achieved a drastic increase in operating speeds.

Porter and Ramsey (*1*) were able to simplify the procedure and confine the discharge equally well with a two-tube feed-back arrangement. They made a deliberate effort to limit the spreading process in order to increase speed and life. Previous studies by Ramsey (*18*) on current time and spreading velocity suggested that, with the argon-ether

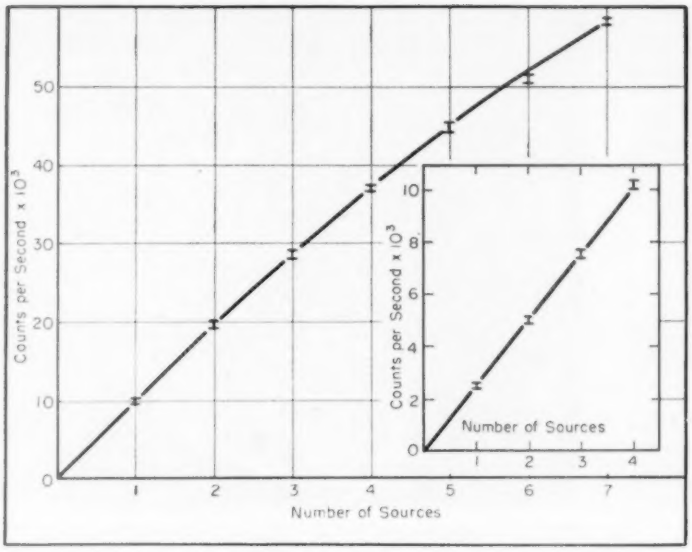


FIG. 3. Counting rates obtained by placing sources to yield 10,000 cps each. Inset curve obtained by placing sources to yield 2,500 cps each

and argon-butane mixtures used, such a simplification might be possible.

By working within 30 volts of the potential characterized by pulse equalization, and minimizing stray capacitances, Porter and Ramsey were able to achieve an insensitive time of 1.5 μsec. An examination of the charge distribution indicated that active ionization had been confined to 1 cm of the tube length.

Circuit operation. Figure 2 shows the two-tube cut-off circuit with a rate-measuring arrangement used for high speeds. All tubes are 6AK5's and all unlabeled by-pass capacitors are 0.0025 μf.

When the pulse from a G-M counter has developed approximately 0.2 volts across R_1, the pulse is amplified enough in V_1 to cause the grid of V_2 to come from below cut-off bias; hence the plate current of V_2 adds to the voltage drop of R_1—a cumulative action which proceeds until V_1 is cut-off. The grid of V_2 starts to recover rapidly by virtue of the short time constants involved. As the grid of V_2 recovers, the plate current of V_2 decreases until the voltage drop across R_1 is less than the cut-off bias of V_1. The resulting negative pulse on the plate of V_1 abruptly returns the grid of V_2 below its cut-off value. The time required for an entire cycle of the circuit operation is approximately 1.5 μsec. After this period, the circuit is again ready to accept a new pulse.

Continuous oscillographic observations of both wire and cylinder were made at all rates. This examination of the wire potential indicated a pulse form controlled by the feed-back circuit, and independent of counting rate up to rates as high as 200,000 cps. It also demonstrated that the normal operating voltage is restored in about 7.5×10^{-7} sec.

Measurements of charge on the cylinder, with and without the circuit operating, indicated that this cut-off procedure reduced the charge to that which would be observed in a tube 1 cm in length. Further discussion of the charge distribution as observed with a tube made with a segmented cathode can be found elsewhere (*1*). Figure 1 illustrates the difference between the usual deadtime picture using Stever's original procedure, and the picture obtained when the cut-off circuit is in operation.

Effect of radiation intensity. To obtain information on the variation of the counting rate of a circuit-controlled counter as a function of the relative intensity of incident radiation, the following procedure was used.

Each of seven radioactive sources was so placed in relation to the counter that a counting rate of 10,000 cps was obtained; the position of each source was carefully marked. Then, starting with one source and adding one source at a time in its marked position, the counting rates corresponding to one, two, three and so on up to seven sources were recorded. In this way, the main plot shown in Fig. 3 was obtained. A thin-walled glass counter, 20 cm long and 0.9 cm in diameter, with a 0.003-in.-diameter wire was used. The inset curve was gotten in a similar manner, with four sources located in relation to the counter so that each source gave a counting rate of 2,500 cps.

The indicated uncertainties in the measured counting rate represent the approximate fluctuations observed on the meter in the integration circuit. A straight line can be drawn through the origin and all of the points on the low-counting-rate curve. All of the rates indicated in this figure are far above those for which the average investigator would trust his counter if used under normal operating conditions.

This circuit has been used successfully at this laboratory with gas mixtures of argon-ether (6.5:1) at approximately 5.5-cm-Hg pressure; argon-butane (6:1) at approximately 8.5 and at 12-cm Hg; and argon-alcohol (4:1) at 8.0-cm Hg. With any of these mixtures and a photon source of radiation, the reduction in pulse height at the cylinder indicated that the discharge had been limited to 1 cm of the total length of the counter. How the circuit will work with other mixtures and with other pressures is not yet known.

* * *

The author wishes to express his appreciation to Dr. W. F. G. Swann, Director of The Bartol Research Foundation, Dr. G. W. McClure and Mr. W. E. Ramsey for many helpful discussions and advice. This work was assisted by the joint program of the ONR and the AEC.

BIBLIOGRAPHY

1. W. C. Porter, W. E. Ramsey, *J. Franklin Inst.* **254,** 153 (1952)
2. W. E. Ramsey, *Phys. Rev.* **57,** 1022 (1940)
3. C. G. Montgomery, D. D. Montgomery, *Phys. Rev.* **57,** 1030 (1940)
4. H. G. Stever, *Phys. Rev.* **61,** 38 (1942)
5. C. O. Muehlhause, H. Friedman, *Rev. Sci. Instr.* **17,** 506 (1946)
6. S. C. Curran, E. R. Rae, *Rev. Sci. Instr.* **18,** 871 (1947)
7. S. C. Curran, E. R. Rae, *J. Sci. Instr.* **24,** 233 (1947)
8. L. G. Parratt, C. F. Hempstead, E. L. Jossem, *Rev. Sci. Instr.* **23,** 1 (1952)
9. I. Nonaka, *J. of the Phys. Soc. of Japan* **7,** No. 1. (1952)
10. A. Trost, *Z. Physik* **117,** 257 (1941)
11. H. V. Neher, W. W. Harper, *Phys. Rev.* **49,** 940 (1936)
12. J. A. Simpson, Jr., *Phys. Rev.* **66,** 39 (1944)
13. A. L. Hodson, *J. Sci. Instr.* **25,** 11 (1948)
14. P. B. Smith, *Rev. Sci. Instr.* **19,** 453 (1948)
15. H. Elliot, *Proc. Phys. Soc. London* **62,** 369 (1949)
16. B. Collinge, *Proc. Phys. Soc. London* **63B,** 15 (1950)
17. H. den Hartog, F. A. Muller, *Physica* **16,** 17 (1950)
18. W. E. Ramsey, *Phys. Rev.* **83,** 242 (1951)

Continuous direct measurement of the reactivity of a reactor can be made by the three methods described here. At the Saclay reactor, a recording potentiometer gives the reactivity in terms of the ratio of power change to power

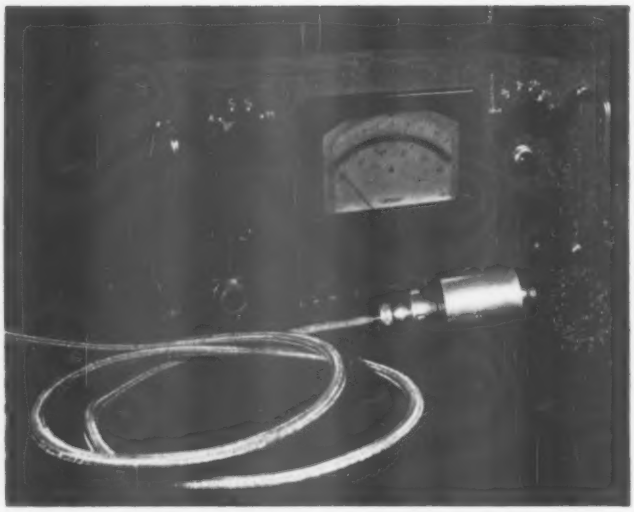


FIG. 1. Logarithmic amplifier showing diode preamplifier at end of cable

Measurement of Reactivity

By JACKY WEILL
Commissariat à l'Energie Atomique
Saclay, France

CONTINUOUS MEASUREMENT of the instantaneous value of the reactivity of a reactor is a great help in predicting changes in the power level. The information so obtained makes it possible to adjust the control rods before a dangerous level is reached.

Furthermore, the influence of the temperature, or of the loading of the reactor by samples for activation, on the reactivity may be more conveniently studied.

Three different procedures have been developed for measuring the reactivity. The first, which is well known, gives the time derivative of the output of a logarithmic amplifier at the input of which a voltage proportional to the power, P, of the reactor is applied.

In the other two procedures, the ratio of the time derivative of the power to the power is obtained. The two methods are:

1. An a-c voltage proportional to dP/dt is applied to the vertical deflection plates of an oscilloscope, while an a-c voltage proportional to P, and in phase with dP/dt, is applied to the horizontal plates.

The Lissajous figure so obtained is a straight line; the tangent of the angle of this line with the horizontal is proportional to the reactivity.

2. Voltages proportional to P and to dP/dt are fed to a recording potentiometer which is connected as a ratio meter. This instrument is used on the Saclay reactor, and is mounted on the control panel.

Photographs of the logarithmic amplifier and the oscilloscope apparatus are shown in Figs. 1 and 2.

The Reactivity

The evolution of the power, P, of an uncontrolled reactor follows an exponential law of the form

$$P = P_0 e^{kt} \tag{1}$$

where

$$k = \frac{m-1}{\tau} = \frac{r}{\tau} \tag{2}$$

In Eq. 2, m is the neutron reproduction factor, τ is the life of the thermal neutrons that produce nuclear fissions, and r is the reactivity of the reactor. When

$r > 0$ the reactor is divergent
$r = 0$ the reactor is critical
$r < 0$ the reactor is convergent

For a heavy-water reactor, $\tau = 10^{-1}$ sec; this value of τ takes into account effects due to delayed neutrons.

The measurement of r requires the measurement of k, since, from Eqs. 1 and 2,

$$r = k\tau = \tau \frac{d \log P}{dt} \tag{3}$$

$$= \tau \frac{dP}{Pdt} \tag{4}$$

Equation 3 suggests the first of the methods: P is applied to the input of a logarithmic amplifier, whose output is differentiated with respect to time.

If one uses Eq. 4, one has to differentiate P with respect to time and divide the result by P. The second and third procedures are based on this

FIG. 2. Oscilloscope apparatus; chopping amplifiers, oscillator, and power supply are on chassis at right

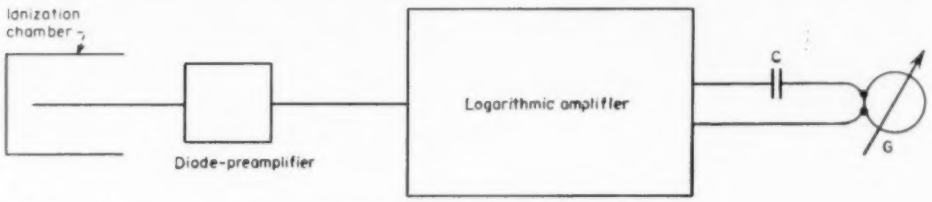


FIG. 3. Arrangement for using logarithmic amplifier and galvanometer

method. The third method is used in the control of the Saclay Pile.

Logarithmic Amplifier

Let I be the current obtained from a slow-neutron ionization chamber placed in the reactor flux. Then $I = AP$, where A is a constant. The ionization chamber is followed by a logarithmic amplifier whose output voltage, v, is proportional to the logarithm of I, and hence

$$v = K \log I = K \log AP = K \log AP_0 e^{kt} \quad (5)$$

where K is a constant.

The output terminals of the amplifier are connected, as shown in Fig. 3, to a circuit consisting of a capacitor, C, and a galvanometer, G, whose internal resistance is r_g.

The voltage V_c across the capacitor satisfies the following equation

$$v = K \log AP_0 e^{kt} = V_c + r_g C \frac{dV_c}{dt} \quad (6)$$

The general solution of Eq. 6 is

$$V_c = ae^{-\frac{t}{Cr_g}} + Kkt + K \log AP_0 - KkCr_g \quad (7)$$

where a is the integration constant.

The time constant Cr_g was chosen to be negligible compared to the galvanometer time constant, so that the term $ae^{-\frac{t}{Cr_g}}$ vanishes rapidly, and hence

$$V_c = Kkt + K \log AP_0 - KkCr_g \quad (8)$$

The current through the galvanometer is

$$i_g = C \frac{dV_c}{dt} = KkC = K \frac{Cr}{\tau} = Br \quad (9)$$

Thus i_g is proportional to the reactivity, r.

The logarithmic amplifier used worked on the basis that under certain conditions the voltage across a diode is proportional to the logarithm of the anode current. With the diodes used, this condition was satisfied in the range 10^{-14} to 10^{-8} amperes.

The constant K is practically the same for all diodes, and its value is 0.2 volt.

The capacitor C has to be well insulated, and, to improve the sensitivity, its capacity should be large; however, Cr_g should be small compared to the time constant of the galvanometer. The practical values chosen were r_g = 1,000 ohms, and C = 500 μf. Under these conditions, a galvanometer current $i_g = 10^{-8}$ amperes was equivalent to $r = 10^{-5}$.

Good results were obtained with this type of instrument. However, this method does not lend itself conveniently to recording, nor does it deliver a signal convenient for controlling the shut-off of the pile, unless the galvanometer is replaced by a sensitive potentiometric recorder with contacts for the shut-off signals.

Oscilloscope Method

A block diagram of the arrangement of equipment for this method is shown

in Fig. 4. The circuit diagrams are shown in Fig. 5.

The principle of the method is as follows. An electronic chopper transforms d-c voltages (proportional, respectively, to P and dP/dt) into a-c voltages. These a-c signals are applied, without relative phase shift, to the horizontal and vertical deflection plates of a cathode-ray tube. The resulting Lissajous figure is a straight line; the tangent of the angle of this line with the horizontal is proportional to dP/Pdt.

A transparent scale calibrated in reactivity is mounted in front of the face of the cathode-ray tube (Fig. 6). The dependence of dP/Pdt on the tangent of the angle is very convenient, since the resulting scale is widely spaced at low values of τ, yet values up to 1,500 may be read off without changing the amplifier gain.

Although mechanical choppers may be used, the transformation of d-c into a-c voltage was performed electronically, the frequency being 1,000 cps.

Notwithstanding its drawbacks (difficulties in keeping the two a-c voltages

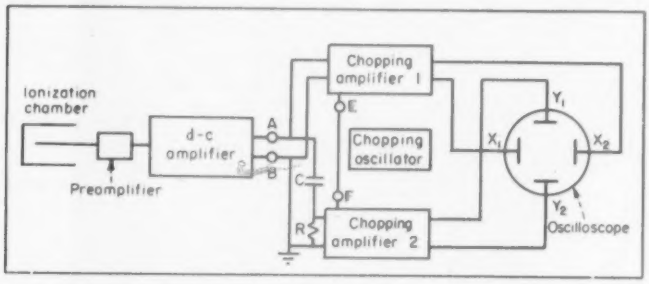


FIG. 4. Block diagram of the oscilloscope method

NOTE: Heater on 12SJ7 should connect to terminals erroneously labeled *A-B* on 120-volt line

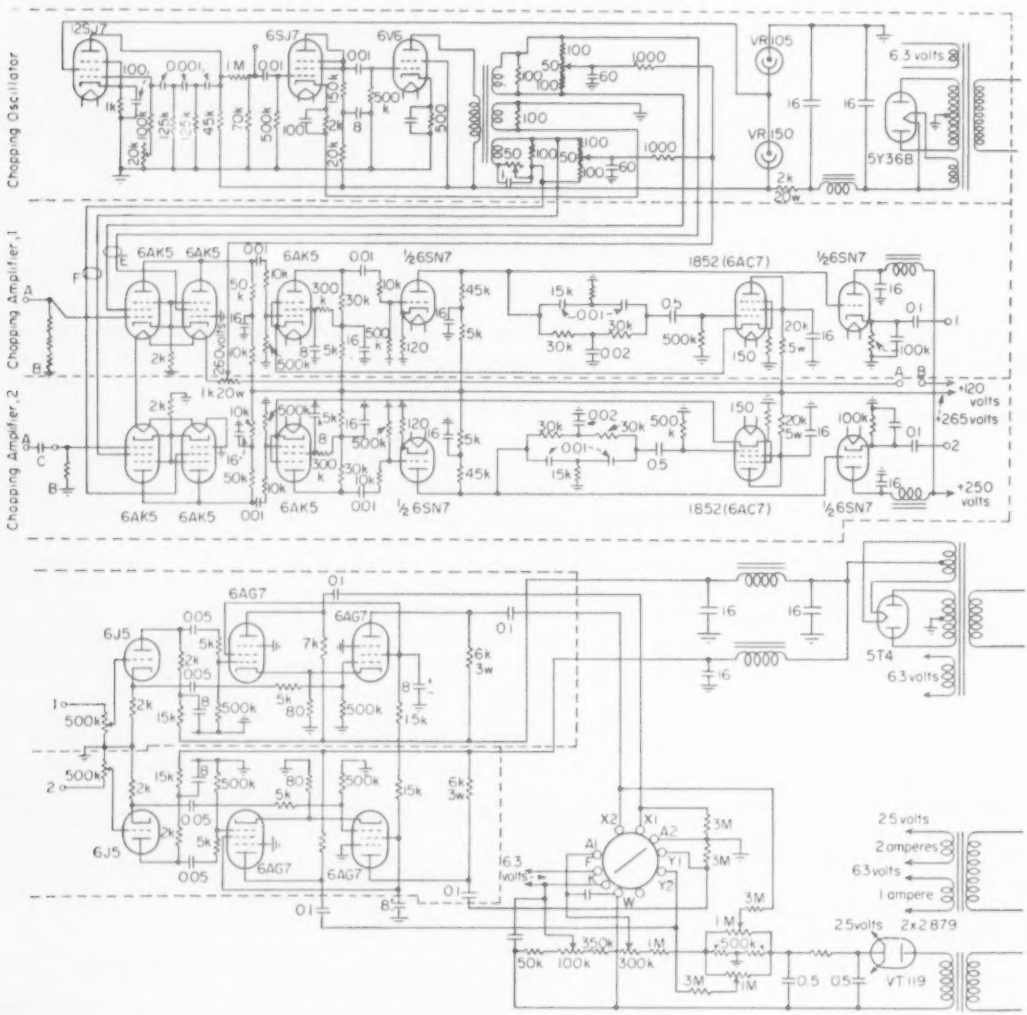


FIG. 5. Circuit diagram of the apparatus shown in Fig. 4

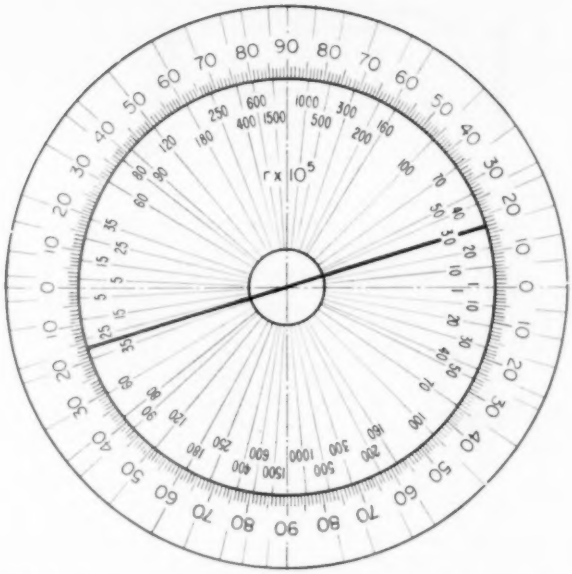


FIG. 6. Transparent scale calibrated in $r \times 10^5$ to be mounted on face of cathode-ray tube

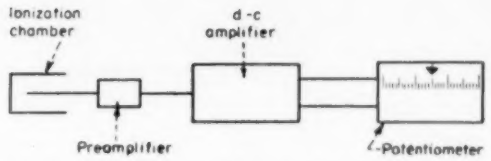


FIG. 7. Block diagram of the potentiometer method

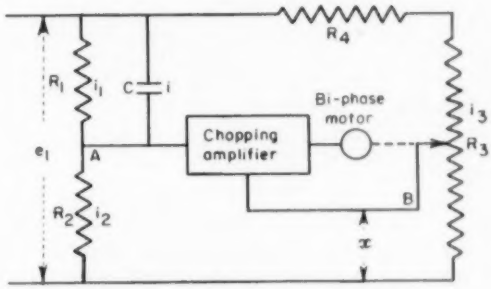


FIG. 8. Circuit of the recording potentiometer

in phase and lack of a convenient method for recording the reactivity and deriving a shut-off signal), this method can be useful.

Potentiometer Method

This method is also based on the division of dP/dt by P; however, here the division is performed by an automatic potentiometer.

A block diagram of the instrument is shown in Fig. 7; it includes the ionization chamber, a d-c amplifier, and a servo-controlled potentiometer recorder.

This recorder comprises a bi-phase motor driving the slider of a calibrated potentiometer. One of the phases of the motor is energized by the line voltage, whereas the other is connected to the output of a difference-amplifier, which is connected so that the slider of the potentiometer is rotated by the motor until its voltage is equal to that at the input of the amplifier. The circuit used is shown in Fig. 8. As will be shown, the displacement of the slider is proportional to $(1/P)dP/dt$.

The position of the slider is recorded on paper; contacts for obtaining shut-off signals may be added at convenient positions.

Theory of the circuit. Let e_1, which is proportional to the power, be the voltage across the circuit of Fig. 8. At equilibrium

$$e_1 = E_0 e^{kt} = R_1 i_1 + R_2 i_2$$
$$i_2 = i_1 + i$$
$$i = CR_1 \frac{di_1}{dt}$$

The equation for i_1 is

$$(R_1 + R_2) i_1 + CR_1R_2 \frac{di_1}{dt} = E_0 e^{kt} \quad (10)$$

The general solution of Eq. 10 is

$$i_1 = Ae^{-\frac{R_1+R_2}{CR_1R_2}t} + \frac{E_0 e^{kt}}{R_1 + R_2 + CR_1R_2k} \quad (11)$$

If one chooses the values of C_1R_1 and R_2 so that $(R_1 + R_2)/CR_1R_2$ is large compared to the mechanical time constant of the recorder, the first term on the right in Eq. 11 vanishes rapidly. Moreover, CR_1R_2k is small as compared to $R_1 + R_2$ and hence

$$i_1 = \frac{E_0 e^{kt}}{R_1 + R_2} \quad (12)$$

On the other hand, at equilibrium, one has

$$x = \frac{R_2 i_2}{R_3 i_3} \quad (13)$$

Using Eqs. 1, 3, and 5 one obtains

$$x = x_0 + \frac{CR_1R_2(R_3 + R_4)k}{R_3(R_1 + R_2)} \quad (14)$$

where the term x_0 is given by the expression

$$x_0 = \frac{R_2(R_3 + R_4)}{R_3(R_1 + R_2)}.$$

Thus x is a linear function of k, and hence of the reactivity r. The power, P, must of course be sufficiently large to give a voltage e_1 large enough to drive the recorder.

The term

$$x_0 = \frac{R_2(R_3 + R_4)}{R_3(R_1 + R_2)}$$

which is independent of the power, enables one to choose the position of the zero of the instrument. We have fixed the zero position at the middle of the recording paper, so that negative values of r may also be recorded.

The instrument built has two scales for r: the first ranges from -500×10^{-5} to $+500 \times 10^{-5}$, and the second from -100×10^{-5} to $+100 \times 10^{-5}$. The scales are chosen by switching in convenient values of R_1, R_2, R_3, R_4, and C.

Instruments of the types described have general application in the measurements of time constants. They may also be used to measure very high resistances, capacitances, and the lifetimes of radioactive elements.

* * *

This article is based on a paper presented at the Third Instruments and Measurements Conference, Stockholm, Sweden, Sept. 22, 1952.

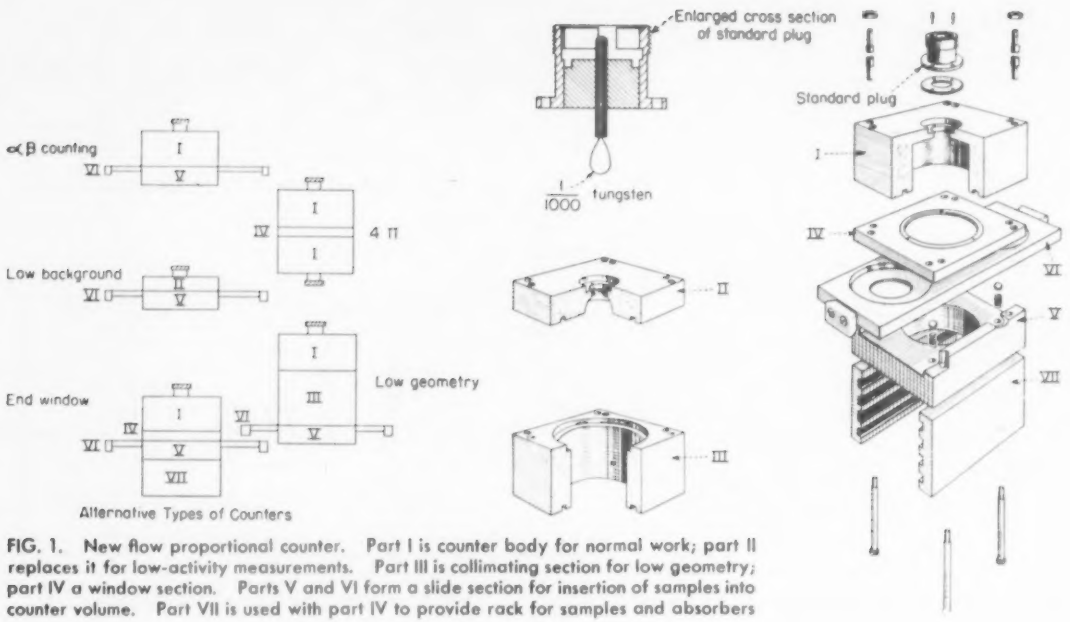


FIG. 1. New flow proportional counter. Part I is counter body for normal work; part II replaces it for low-activity measurements. Part III is collimating section for low geometry; part IV a window section. Parts V and VI form a slide section for insertion of samples into counter volume. Part VII is used with part IV to provide rack for samples and absorbers

Recent Instrument

A very versatile proportional counter, a new scaler circuit using decade scaling tubes, an automatic data analyzer, flame-proof monitoring instruments, logarithmic-scale survey meters, and portable bore-hole logging apparatus have been developed at the Atomic Energy Research Establishment

By DENIS TAYLOR
Atomic Energy Research Establishment
Harwell, England

APPARATUS DESIGNED for each particular task is gradually replacing the general-purpose instruments first used in the British Atomic Energy Project. The general-purpose instruments were standardized early in the project's history to allow large-scale manufacture, but growth of the project has led to new instrumentation requirements.

Counting Instruments

Much use is being made in Britain of halogen-quenched Geiger counters. These counters are now available in a number of forms (*1*). They have very low temperature coefficients and almost infinite lives. Moreover, they can be manufactured to operate at precisely defined voltages throughout their lives. Thus it is satisfactory to use a counter power supply that gives a fixed output voltage; this has led to considerable simplification of apparatus. Corona voltage-stabilizing tubes are used in these power supplies.*

Proportional counters. For certain types of radioactive assay, particularly when high accuracy is required, it is often preferable to use a proportional counter rather than a Geiger counter. Although sealed-off proportional counters are being used, greater use is being made of flow counters.

As many variants of the flow counter are required for different purposes, a universal design has been evolved that allows different types to be assembled from a few standard parts. The standard parts and some typical assemblies are illustrated in Fig. 1.

A simple flow-type counter suitable for alpha counting with argon as the flow gas is formed from parts I, V and VI. The operating voltage with an anode loop of 1/1,000-in. tungsten is 800 volts, and the background is 10

* These corona tubes are manufactured by Nucleonic and Radiological Developments, Ltd., Leadenhall St., London, E. C. 3, England.

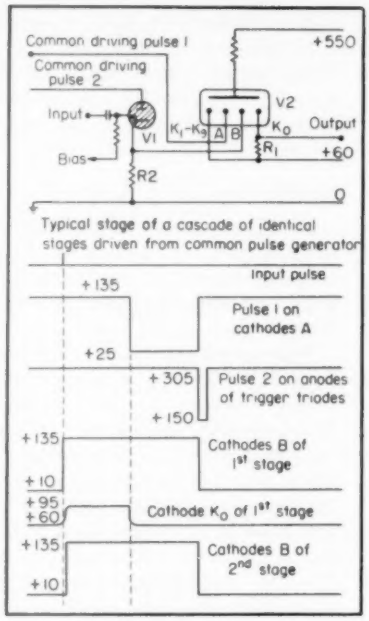
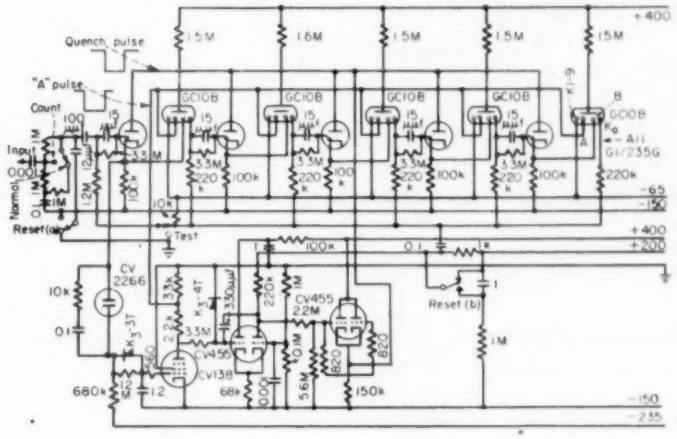


FIG. 2. Waveforms and drive circuit for decade scaler

FIG. 3. Circuit of complete decade scaler



Developments in England

counts per hour. The same system can be used for beta counting, but methane gas and an operating voltage of 2,500 must be used.

A low-background alpha counter for very low activities is obtained by substituting part II for part I. Background is about 1 count per hour.

An end-window beta counter with provision for absorber changing, a low-geometry alpha or beta counter, and a 4π alpha or beta counter are also shown in Fig. 1. For the last, two counter bodies are employed, one on each side of a very thin sample of the material being assayed.

Scalers. Changes have also been introduced into the associated scaling equipment. Almost all the latest British counting apparatus employs cold-cathode decade scaling tubes. These tubes consist of a central anode surrounded by 30 wires that form three interlaced systems of 10 wires each. These are termed the cathode, first-guide (*A*) and second guide (*B*) systems respectively.

When these tubes were introduced, they were operated (*2*) so that a glow discharge was normally left burning between the anode and cathode. The application of two suitably-spaced pulses to the *A*- and *B*-electrodes, in turn, then transferred the discharge from one cathode to the next in the correct order.

In the system now employed (*3*), the *B*-electrode is normally left burning, and the *A*-electrodes of all the decade scaling tubes, in a cascade of such tubes forming a complete scaler, are operated from a common source. This is pulse 1 shown in Fig. 2. In a similar way the anodes of all interstage cold-cathode coupling triodes are operated from a common source. This is pulse 2 shown in Fig. 2, or the quench pulse of Fig. 3.

These waveforms are produced by a double-triode pulse generator. On receipt of an input pulse from the counter, this unit generates two 800-μsec pulses, the second being triggered from the back edge of the first. Finally, the back edge of the delayed pulse (pulse 1) generates a 50-μsec pulse that quenches the cold-cathode triode and at the same time advances the glow to the next *B*-electrode.

Figure 3 shows the complete circuit for a scaler of this type using Ericsson's type GC10B decade scaling tube. With this circuit the input resolving time is about a millisecond; this limits the maximum counting rate to about 50 cps. But a very large percentage of the measurements in this project involves counting rates less than this figure, and the scaler is becoming deservedly popular.

Advantages of this scaler over the orthodox double-triode scaler are that fewer components are needed, power requirements are much lower (by a factor of about 100), and the instrument can be much more compact. A battery-powered scaler has been made for field use.

New cold-cathode decade scaling tubes, interchangeable with the GC10B but with different gas fillings, are being used experimentally. Resolving times of about 100 μsec have been achieved, and it seems likely that this will ulti-

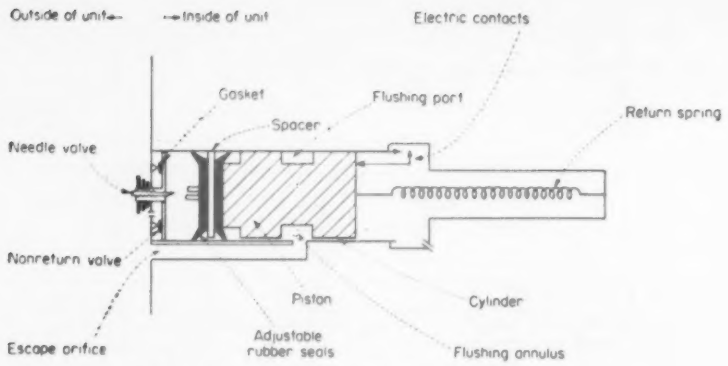


FIG. 4. Pressure switch used in flame-proof monitors

mately be reduced by a factor of at least 2 and probably 5.

Automatic Apparatus

Automatic apparatus is being used on an increasing scale to aid both routine assay work and fundamental research. An interesting example of the latter application is the machine recently constructed for analyzing cosmic-ray observations. In one experiment being carried out by T. E. Cranshaw at Harwell, 16 counters are arranged in a square lattice. At each coincidence of three or more counters, the location of those triggered is recorded photographically. The relative coincidence of the possible configurations of 14 different types are then obtained by examining the film.

Repeated checks on the same film have shown that it is easy to overlook a configuration. To overcome this difficulty, equipment has been built that automatically recognizes all possible configurations and displays on 14 registers the totals for each type.

The principal component in the system is a motor-driven uniselector, operated in conjunction with wiper switching relays as a 5-bank, 150-contact switch. Associated with the 140 combinations (of 14 different types) that the analyzer is required to detect are 140 contacts. The uniselector reaches a rate of 200 contacts per second until it reaches the first combination pattern set up on the 16 input switches representing the counters. The control circuit arrests the uniselector on this contact, impulses the appropriate register, and then moves the wipers onto the next contact by an independent slow drive circuit. If this contact represents a combination that is not present in the input, the fast drive circuit comes into operation again. When all the combinations have been inspected, the uniselector stops and a "finish" lamp lights.

Health-Physics Instruments

Many new radiation monitors are now in use in the project. Included are high-current counters, flame-proof monitors, and logarithmic-scale instruments.

High-current counters. Increasing use is being made of halogen-quenched Geiger counters as d-c chambers. These so-called high-current counters can be designed to give currents of about 25 μa* when operated in moderate gamma-ray fields; in many cases no amplification is required (*4*). At Harwell a number of health-physics instruments using these counters are used to measure dose rates of the order of the ordinary occupational tolerance value (12.5 mr/hr) or less.

One such instrument is a monitor that is installed in vehicles transporting radioisotopes. The radiation detector, a high-current counter, is placed immediately behind the driver's seat; the dose rate at this position is indicated by the meter of a dashboard-mounted monitor comprised of an electrometer triode followed by a vacuum-tube voltmeter. Colored lights, green for

* High-current counters with anode wires up to 5 mm diameter have been reported as giving currents up to 500 μa.

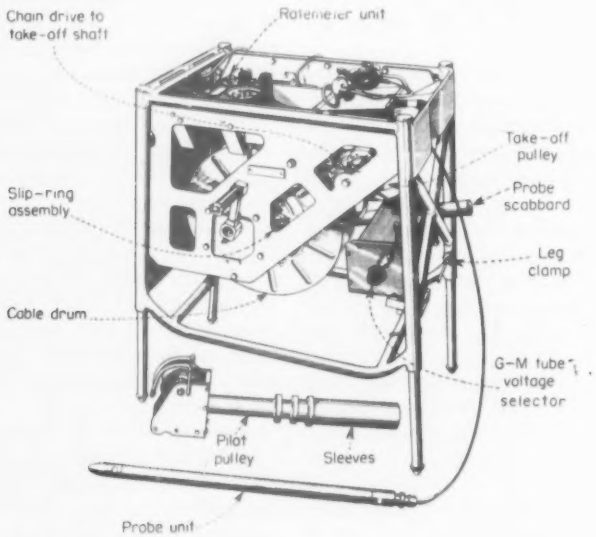


FIG. 5. Borehole logging equipment

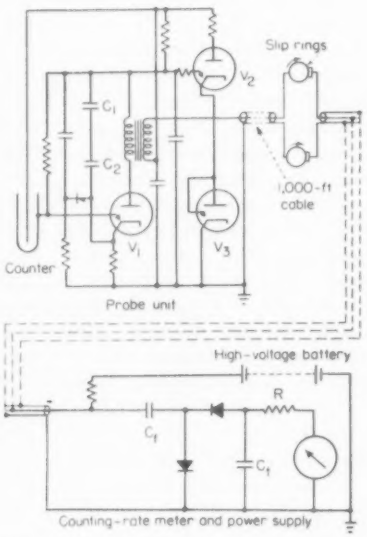


FIG. 6. Circuit of logging equipment

1 tolerance, yellow for 3 and red for 10, are also operated on the dashboard. All power supplies are obtained from the car battery.

Flame-proof instruments. A necessary feature of health-physics instruments used in areas where flammable vapors (e. g., ether vapor) may be expected is that they be flame proof. This feature can be obtained by maintaining excess internal air pressure above atmospheric in the apparatus during operation. Instruments using this principle are giving very satisfactory service in the vicinity of pilot chemical plants at Harwell.

Key to operation of the flame-proof units is the control valve shown in Fig. 4. When a unit is to be used, air is injected through a pressure-reducing valve. After circulating through the unit, the air pushes the piston of the control valve forward towards the needle. The time taken for the piston to move sufficiently to close the electrical connection is governed by the needle-valve setting.

In moving, the piston uncovers a flushing port in the cylinder wall; this allows air to circulate round the annulus and out to the atmosphere through the flushing orifice until the electrical contact closes. This takes about 10 minutes, and the air in the monitor will have diluted at least 100:1 so that any flammable gases trapped inside are not present in dangerous concentration.

If at any time the internal pressure falls below $1\frac{1}{2}$ lb/in^2 the return spring pulls back the piston, releasing the contact and switching off the supply.

Logarithmic-scale meters. All early ionization-chamber electrometer-tube monitors in use in the British project had linear scales, but considerable use is now being made of electrometer circuits with a free or floating grid to give a logarithmic scale. These logarithmic-scale instruments allow several decades to be covered without range-switching and its reading errors.

The main disadvantage of a logarithmic scale is reduced accuracy, but this difficulty does not arise in health monitoring where an accuracy of $\pm 25\%$ is usually more than sufficient.

Geological Instrumentation

A final example of instrumentation developments at the AERE is the borehole logging equipment used for locating radioactive deposits in the earth's crust. For boreholes 2 in. or more in diameter, there is a great deal to be said for using scintillation-counter detectors, particularly for deep boreholes. For boreholes of smaller diameter, however, Geiger-counter detectors are usually quite acceptable.

The equipment described here is designed for measurement of changes in intensity of gamma radiation. The sensitivity chosen is better suited to mine control than more general stratographic logging.

For mine control, provision must be made for logging of downward sloping holes, upward holes and holes near horizontal. The equipment must be robust, reliable and unaffected by moisture, and capable of being used and maintained by a geologist without electronics training. Size, shape and weight must be such that the unit can even be transported along tracks inaccessible to vehicles and within mines.

Figure 5 shows the apparatus designed to meet these requirements. The probe, a stainless-steel tube with a bullet-shaped nose, is glanded to a single concentric cable and sealed to withstand 700 lb/in^2 hydraulic pressure.

The cable is covered with a 0.01-in. Nylon film to resist abrasion. Three of the seven inner-conductor strands are high tensile steel wire with a breaking load of 300 lb, and the cable both supports the probe and provides an electrical connection to it.

The basic circuit of the complete apparatus is shown in Fig. 6. Discharge of the counter raises the current across the trigger cathode of V_1 sufficiently to cause V_1 to conduct. The series capacitors then discharge through the tube and the primary of the impedance-matching transformer. This causes an electric impulse in the secondary that is fed through the cable to the counting-rate circuit. With cold-cathode tubes, total power consumption is only 20 mw.

The scintillation version of this equipment uses an EMI type 6260 photomultiplier.

Push rods. To insert the probe into horizontal and upward boreholes, push rods must be used. Those designed by J. B. Marsh (*5*) are shown in Fig. 7. They consist of 1-meter tubular half-sections that interlock to form a complete tube equal in diameter to the probe. These push rods are used in lengths up to 100 meters.

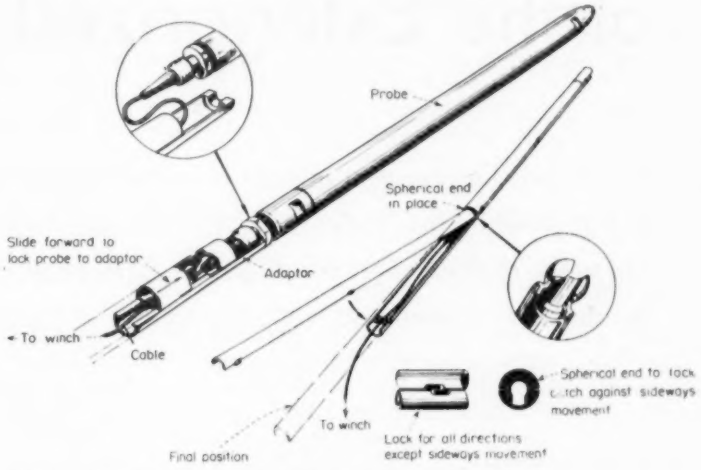


FIG. 7. Push rods for use with borehole logging probe

* * *

I am indebted to several of my colleagues at the AERE who have provided me with information for this article. In particular, I am indebted to Mr. Kandiah for information about the decade scaling circuit, Mr. R. C. M. Barnes for information about his cosmic-ray analyzer, Mr. J. Sharpe for data about his universal flow counter, Mr. Pulsford for information about the vehicle monitor, and Dr. Franklin and Mr. D. Williams for information about their borehole logging equipment. This article is based on a lecture given at the Third Instruments and Measurements Conference, Stockholm, Sept. 22, 1952, and is published by permission of the Director, Atomic Energy Research Establishment.

BIBLIOGRAPHY

1. N. B. Balaam, *Electronic Engineering* **24**, 558 (1952)
2. D. Taylor, NUCLEONICS **9**, No. 6, 5 (1951)
3. K. Kandiah, British patents 8914/52 and 23557/52
4. H. D. LeVine, H. J. DiGiovanni, M. R. Coe, NUCLEONICS **6**, No. 6, 56 (1950)
5. J. B. Marsh, British patent 12975/52

Preliminary Report on

Anemia in Mice Resulting from Irradiation of the Exteriorized Spleen

The blood changes that take place when the spleen is exposed to X-rays while the body is shielded are now being studied. The work complements the Argonne experiments in which the body was irradiated while the spleen was shielded

By BRUCE ALLEN
Radiological Research Laboratory
Columbia University
New York, New York

THE WORK of Jacobson and his collaborators* has shown that shielding the surgically exteriorized spleen while exposing the entire body of a mouse to a large dose of X-rays prevents, or at least reduces, the development of anemia during the first week following irradiation. Furthermore, intraperitoneal implantation of splenic tissue following total-body exposure to X-rays has a similar effect.

To throw further light on this interesting and important phenomenon, it was decided to irradiate only the exteriorized spleen of the mouse and to study any possible hematological

Red Blood Cells in Millions per Cubic Millimeter (Mice)

Days after irradiation	*Group 1* (TBx)	*Group 2* (SE + TBx)	*Group 3* (SE)	*Group 4* (SEx)	*Other experiments* (SEx)	
					4 CF₁	*5 Swiss*
0	10.30	10.30	10.30	10.30	9.87	8.71
1	10.06	9.32	9.99	8.62	8.50	8.46
2	9.22	9.72	10.20	9.60	....	7.76
3	9.99†	9.52†	9.59	8.53	7.76	7.16
4	8.25†	8.13§	9.25	7.28	7.69	6.99
5	8.93‡	8.06§	9.05	6.81	....	....
6	.....	.....	9.20	6.55	....	....
7	.....	.....	8.70	6.50	....	....

† 4 alive. ‡ 2 alive. § 1 alive.

* L. O. Jacobson *et al.*, ANL-4401 (1949–50).

changes. These experiments are described in this preliminary report.

Experimental Procedure

The animal was anesthetized with Nembutal in a 1 to 10 solution, and the spleen was exteriorized with as little trauma as possible. For irradiation, the spleen was pulled to one side and placed in a small pad of gauze soaked with physiological saline solution resting on a $\frac{1}{16}$-inch Lucite shelf. Two small Lucite pegs, one on each side of the body of the spleen, prevented it from slipping back into the body.

The spleen was irradiated by a beam of X-rays passing through a hole in a $\frac{3}{8}$-inch lead shield that covered the entire body of the animal. An open space was provided under the $\frac{1}{16}$-inch Lucite shelf to avoid scattered radiation that might otherwise reach the body of the mouse.

In the case of the control animals in which the spleen was exteriorized, the same manipulations were carried out, except for the exposure to X-rays.

Irradiation. A dose of 1,025 roentgens was administered in 3.5 minutes with a 250-kv Westinghouse constant potential machine, with the following factors: 210 kv, 15 ma, 0.25 mm Cu and 0.5 mm Al filter, and 30 cm target-to-source distance.

Groups. Twenty two-month-old CF_1 mice were used, in four equal groups as follows:

- Group 1. No operation, total body X-irradiation (TBx)
- Group 2. Spleen exteriorized, total body X-irradiation (including spleen) (SE + TBx)
- Group 3. Spleen exteriorized but not irradiated (SE)
- Group 4. Spleen exteriorized and X-irradiated (rest of body shielded) (SEx)

Blood counts. Blood samples were taken from each animal daily by snipping off a piece of the tail. Red, white, and differential counts were made.

Weights. Each animal was weighed daily.

Results

The finding of chief interest is anemia produced in mice in which only the exteriorized spleen was irradiated.

The daily red blood counts are tabulated on the previous page as averages for each of the four groups. The results of two other experiments are also given in which four CF_1 and five Swiss mice were used and in which only the exteriorized spleen was irradiated. In view of the small number of animals used, it is well to state that no large fluctuations from the average occurred in the cell counts of individual animals in each group.

Irradiation of the exteriorized spleen alone with 1,025 r produced a considerable drop in the red cell count. Blood smears showed the presence of enlarged basophylic erythrocytes (approximately in the ratio of 1 to 50) and many spherocytes. These cells became increasingly more evident after the third postirradiation day. Blood samples were centrifuged in hematocrit tubes on the third and fifth days; the plasma in the group 4 animals (spleen alone irradiated) was found to be yellowish orange in color, indicating hemolysis. The changes in red cell counts and in appearance of the cells in this group are the more striking, since they were apparently more marked than those found in moribund animals whose entire body had been irradiated (Groups 1 and 2).

While obviously the number of animals used so far is too small to permit definite conclusions, there are strong indications that irradiation of the spleen alone produces marked blood changes indicative of hemolytic anemia.

The whole-body irradiated animals lost weight rapidly, whereas the mice in which only the spleen was irradiated gained some weight. Animals in the latter group showed a marked edema on the fourth day. They appeared lethargic and uninterested in their surroundings.

Discussion

In view of the fact that implantation of spleens into a mouse that has received total body irradiation "counteracts" the radiation effect, Jacobson has postulated that the living cells of the nonirradiated spleen produce some humoral factor (or factors) that brings about an early *recovery* of the bloodforming tissue. In this case (spleen implantation), it is obvious that whatever mechanism is involved tends to counteract the initial damage already done by the radiation. However, since irradiation of the spleen alone produces marked anemia, the anemia observed in total-body irradiated mice may be due (at least in part) to the effect of the radiation on the spleen. This is plausible in view of the time sequence of events. In both total-body irradiated mice, and spleen-only irradiated mice, the anemia appears within a few days. This means that by some mechanism (which need not be the same) red cells are "removed" from the circulating blood.

It is known that radiation can produce marked changes in the bone marrow, but then the anemia is presumably a late manifestation of the damage to the cells that produce the red cells. Therefore, an obvious extension of the present work is the study of the mechanism by which the irradiated spleen "removes" red cells from the circulating blood, or in more general terms, causes the anemia. This will have some bearing on the interpretation of the spleen-shielding phenomenon. However, the protective effect of subsequent spleen implantation requires that the nonirradiated implanted spleen do something to counteract the process by which anemia would be produced by the irradiation of the animal's own spleen. The humoral factor postulated by Jacobson should then be something elaborated by the normal (nonirradiated) spleen. This factor must be present in the blood (bloodforming tissue, or, at any rate, in the body) in a certain concentration to maintain the proper number of erythrocytes in the blood and the normal functioning of the bloodforming organs themselves.

If it is further assumed that the factor is utilized or used up rapidly and that continual production is necessary to maintain the required concentration, it follows that radiation damage to the spleen tending to stop or reduce the rate of production of the "factor" would produce anemia in a short time. When a nonirradiated spleen is implanted in the animal, the missing "factor" is provided and the balance is restored, at least to some extent. It is known, however, that implantation of some other tissues* has a similar effect and, therefore, the situation is much more complex than indicated here. Furthermore, irradiation of the spleen alone produces other effects (e.g., edema) not yet studied.

* * *

This article is based on work performed under Contract AT-30-1-Gen-70 for the U. S. Atomic Energy Commission.

* L. O. Jacobson, *Cancer Research* **12**, 315 (1952).

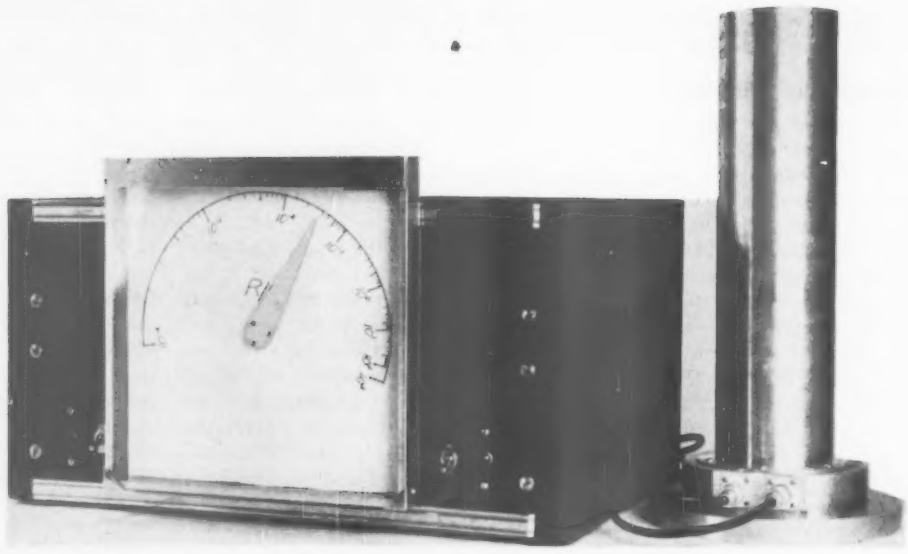


FIG. 1. Complete instrument. Scale is roughly logarithmic

An Improved Wide-Range Radiation Instrument

A self-balancing servo-potentiometer system, by maintaining constant photomultiplier current output, indicates dosage rate as a function of dynode voltage. The instrument covers a dosage-rate range of 10^7 without scale switching

By G. M. BURGWALD and L. REIFFEL
Armour Research Foundation
Illinois Institute of Technology
Chicago 16, Illinois

THE WIDE RANGE of gamma-radiation levels encountered in present-day experiments makes automatic ratemeters with extreme dynamic range very desirable. Such an instrument has been described by us in a previous paper (*1*).* We felt that this device justified further development.

In the earlier instrument, a dosage-measuring range of 10^5 was achieved with a specially tapped nonlinear potentiometer together with a servo system. The present instrument, Figs. 1-3, utilizes the variable-gain characteristics of the photomultiplier tube used in the scintillation-counter detector to yield a range of 10^7.

A block diagram is shown in Fig. 4. The detector consists of a 5819 photomultiplier tube viewing either a sodium iodide crystal (2 in. in diameter and 2 in. long) or a pyrene-in-xylene solution. The output pulses from the tube are integrated, and the d-c voltage, so obtained, is compared to a fixed reference voltage derived from the high-voltage supply. The difference of the two voltages, the error signal, is converted to a-c, amplified, and used to drive a servo motor in the usual manner. The servo motor, in turn, drives the rotary arm of a linear potentiometer connected across the fixed high-voltage supply. The tube voltage is obtained from the potentiometer tap.

Power Supply

In such a system, the voltage across the photomultiplier decreases as the radiation level increases, so that the output current remains constant. The gain varies approximately logarithmically with applied voltage over a range of 10^7 as the voltage is varied from $\sim$1,000 volts to $\sim$200 volts.

*Since the present work was completed, R. E. Bell and R. L. Graham [*Rev. Sci. Instr.* **23**, 301 (1952)] have described a similar technique.

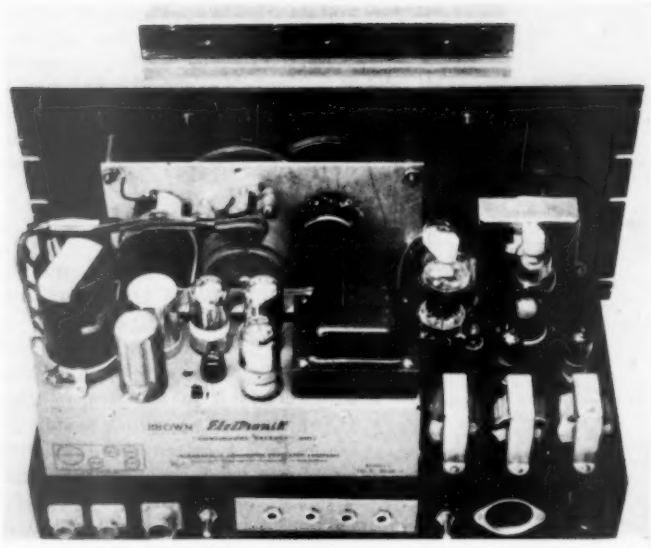


FIG. 2. Rear view of chassis[1]

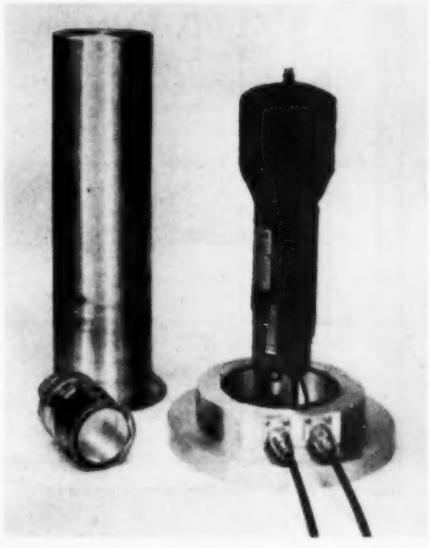


FIG. 3. Detector unit. NaI crystal is at left; pyrene-xylene container is attached to 5819 tube

The complete circuit diagram of the unit is shown in Fig. 5. The high-voltage supply is a conventional degenerative regulator with an output of 1,000 volts. A 300,000-ohm, 10-turn Helipot is used to provide the variable voltage. Since the current through the Helipot is large compared to the current taken by the tube and its associated dynode voltage-divider network, the potentiometer rotation–voltage curve is essentially linear.

The reference voltage for the servo system is also derived from the high-voltage supply for convenience. The photomultiplier load resistor is 20 megohms, and the reference voltage is set at approximately 0.2 volts, so that the normal anode current is 0.01 μa. This low anode current insures that no fatigue effect will be encountered under balanced conditions at any radiation level. The reference voltage is adjustable over a small range so that the instrument can be calibrated.

Servo System

The servo amplifier and motor were taken from a standard Brown "Electronik" recorder. The input transformer of the amplifier was removed, and the photomultiplier signal and the reference voltage connected directly to the converter. A twin-T filter was used at each of the inputs to the converter to reduce 60-cycle pickup.

A 37-rpm servo motor is geared down such that approximately 1 sec

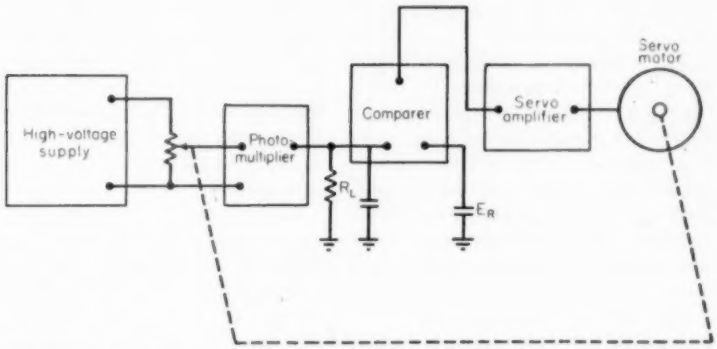


FIG. 4. Block diagram of circuit

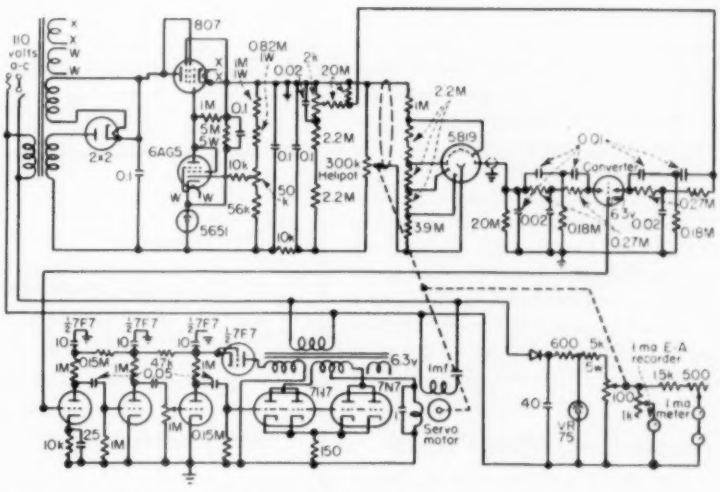


FIG. 5. Complete circuit diagram of instrument

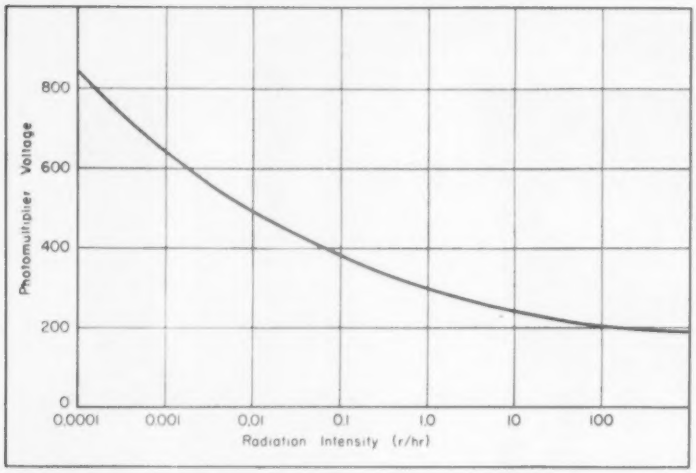


FIG. 6. Typical radiation-vs-voltage curve

is required for the instrument to reach 90% of its final reading at any point on the scale. Scale indication is, of course, obtained by gearing a pointer to the Helipot shaft.

The response of the servo system must be fast for two reasons: (1) unless the photomultiplier voltage is reduced as fast as the radiation increases, there is danger that the tube will be fatigued; (2) if the error signal is allowed to reach too large an amplitude, the servo amplifier will block and phase shifts will prevent the attainment of a final balance.

The speed of response can be increased to the point where statistical changes in the radiation at low levels cause the system to fluctuate with an amplitude sufficient to wear the potentiometer excessively. If a longer period of integration is used to reduce statistical fluctuations in this uncompensated servo, overshoot will develop. In practice, for the range of radiation of interest, an excellent compromise can be made, and the system operates very satisfactorily at levels down to 10^{-4} r/hr at the quoted response time.

A second potentiometer is geared into the servo system and used to drive a 1-ma Esterline-Angus recorder and a number of external meters which serve as repeaters for the indicated radiation level. Adequate mechanical power is available to drive any alarm circuits and/or repeaters required.

Temperature, Voltage Effects

The stability of the unit is limited primarily by the changes in the high-voltage supply and by changes in the dark current of the photomultiplier with temperature. Changes in line voltage from 90 to 130 volts change the reading by less than 10% at all points on the scale. Where better regulation is required, a Sola constant-voltage transformer may be added. With this system, the load resistor may be chosen so that leakage does not become a problem.

Under normal circumstances, the dark-current variations with temperature may be rendered ineffective by setting the minimum detectable signal at ten times the dark current. If abnormal temperature variations are encountered sufficient to change the dark current seriously, or if the range of the instrument must be extended below 10^{-4} r/hr, it is possible to cancel the dark current by introducing another tube signal in series with the servo reference voltage. The second photomultiplier derives its operating voltage from the same supply as does the detector tube, but does not view a scintillation crystal. With the proper choice of photomultipliers and dynode voltage distribution, it is possible to cancel both the dark current and the direct response of the detector to radiation.

Scintillators Tested

The unit has been calibrated at intensities up to 500 r/hr to an accuracy of about 10% using cobalt-60. A curve of tube voltage vs radiation level is shown in Fig. 6. When sodium iodide is used in the detector, an afterglow is observed amounting to approximately 0.03% of the original radiation level for an irradiation time of 2.5 min. The afterglow decays with a half-life of about 4 min under these conditions.

Where afterglow is deleterious, a scintillating solution of pyrene in xylene, which does not afterglow, may be employed. Pyrene has the advantage of fluorescing in the green where self-absorption in the solution is negligible; therefore very large detector volumes may be employed (*2*). With such an organic solution, the instrument is very closely tissue equivalent. However, a loss in sensitivity of a factor of about five is experienced in comparison with sodium iodide.

The device has proven both useful and reliable and is at present being employed in a study of phosphor afterglow phenomena.

* * *

The authors express their appreciation to Mr. A. R. Brauner for his construction of the final model. Patents are pending on the novel features of this instrument.

BIBLIOGRAPHY

1. L. Reiffel, G. M. Burgwald, *Rev. Sci. Instr.* **20**, 711 (1949)
2. E. P. Ney, D. M. Thon, *Phys. Rev.* **81**, 1068 (1951)

Correction

In the process of editing the article "Cobalt-60 Irradiation Chamber," by M. A. Greenfield, L. B. Silverman, and R. W. Dickinson (NU, Dec., 1952, p. 65), the following acknowledgement was inadvertently omitted: "The kindness of Dr. E. J. Hart at Argonne in demonstrating his chamber and supplying a set of working drawings greatly facilitated the design of our own chamber."

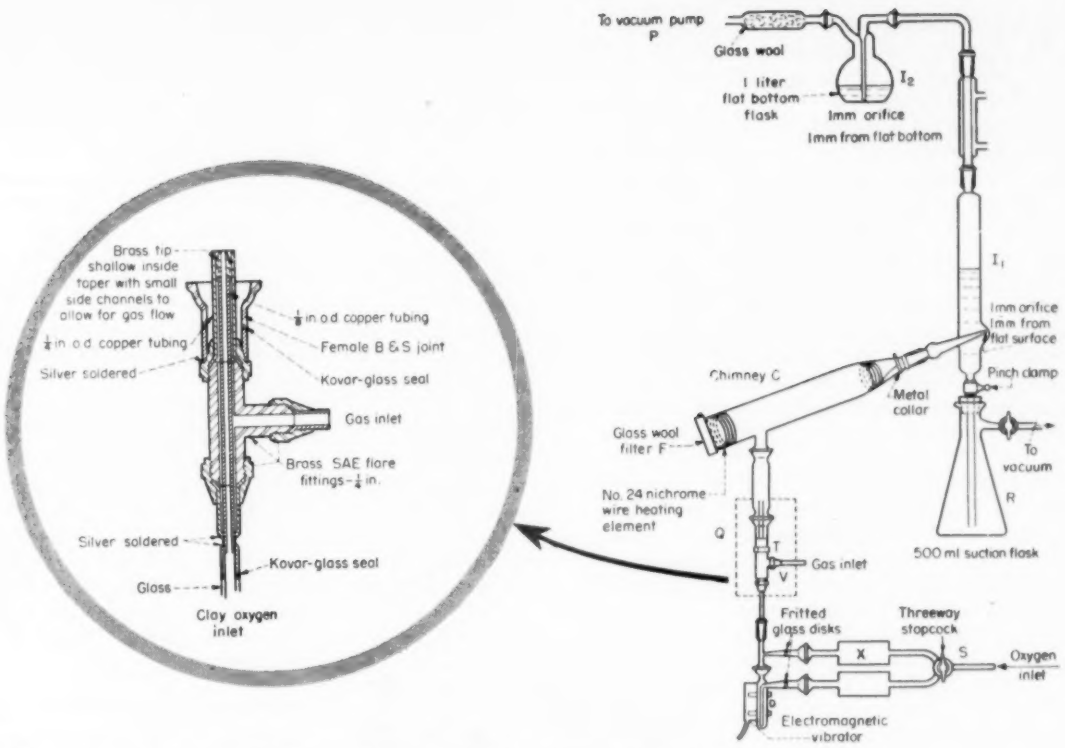


FIG. 1. Apparatus for making clay beads by passing particles in oxygen steam through gas torch

Preparation of Tagged Spherical Clay Particles

Montmorillonite-clay particles, containing radioactive ions and fused and stabilized by heat treatment, are suitable as inert, insoluble tracers or for porous sintered sources. Particle shape is uniform, and size range is relatively narrow

By W. S. GINELL and G. P. SIMON
Department of Nuclear Engineering
Brookhaven National Laboratory
Upton, New York

A RECENT STUDY in this laboratory on the problem of the ultimate disposal of radioactive nuclear fission wastes involved an investigation of some of the cation exchange properties of the clay mineral montmorillonite. The results suggest the use of fused, tagged clay spheres for tracer studies and radiotherapy.

It was found possible to replace the naturally occurring exchangeable cations in the clay by fission-product cations. When the mineral structure was thermally altered, the exchange properties were lost to a very great extent and the radioactive ions were rigidly bound within the particles of the resulting mineral. The thermal treatment was carried out in two ways:

1. By heating the powdered clay containing exchanged radioactive cat-

ions in a muffle furnace to 1,000° C.

2. By passing the clay, suspended in a stream of oxygen, through an oxygen-illuminating gas torch.

Method **1** resulted in a hard sintered, radioactive mass which had to be hand ground. In method **2**, the individual clay particles, on passing through the flame, remained in the hot zone long enough to become fused and to assume a spherical shape. On passing out of the hot zone, cooling was sufficiently rapid for the fused particles to retain their spherical shape. The maximum temperature of the clay in the flame, as measured with an optical pyrometer, was about 1,100° C.

Bead-Forming Apparatus

The apparatus used in the preparation of these spherical beads is shown in Fig. 1. Pump *P* pulls a steady stream of air through the dust filter *F*, up through the chimney *C*, and into the inclined primary impinger I_1, which contains a suspension fluid (usually water). The radioactive clay is placed in the distributor *D* to which is attached a small electromagnetic vibrator.

With the apparatus disassembled at point *Q*, a flame is established in the torch *T* by admitting gas through *V* and oxygen through the bypass *X*. The torch is reassembled and the oxygen flow diverted from the bypass to the distributor by means of stopcock *S*. The clay particles are entrained in the oxygen stream and are carried upwards into the burning zone. The heated clay and the products of combustion pass into the chimney and are transported by the air stream into the primary impinger, where the particles are removed. Any aerosol spray which is carried over from I_1 is trapped in the secondary impinger I_2 and the glass-wool filter.

Upon completion of the run, oxygen is again diverted to the bypass, and the flame is then extinguished. Suction is applied to the receiver *R*, whereupon the suspension of spheres is removed from the impinger.

Physical Properties of Beads

The spherical beads ranged in diameter from 0.5 to 20 microns with more than 80% falling in the 1–4 micron range. Figures 2 and 3 show, respectively, optical and electron microscope photographs of the final product.

Diffraction studies. The powder X-ray diffraction pattern of the spheres was typical of a glass. However, after annealing at 920° C for 24 hr, the pattern obtained was identical with that given by another sample of clay which had received a muffle-furnace heat treatment at 920° C.

The X-ray diffraction studies by Grim and Bradley (*1*) indicated that, at 900–1,000° C, montmorillonite undergoes an irreversible exothermic change resulting in the formation of a new phase which they identified as beta quartz. The "d" spacings of the annealed spheres correspond very closely with the values given by Grim and Bradley for beta quartz. The other phase or phases making up the substrate have not yet been identified.

Exchange studies. The structural change in the clay was accompanied by a corresponding loss of ion exchange properties as was shown by the results of several ionic replacement tests employing spheres containing Ce^{144}-Pr^{144}. The clay employed in all of these experiments was a predominently calcium-saturated montmorillonite.

A 3-gm sample was shaken for 24 hr at room temperature with 100 ml of a 0.1*M* solution of $Ce(NO_3)_3$ containing Ce^{144}-Pr^{144}. After this period, the clay was centrifuged, washed once with water and twice with alcohol, and dried at 110° C. The spheroidizing process was then carried out.

It was found that on refluxing the beads with physiological saline or distilled water for four days, less than 0.1% of the total activity was released. A more stringent test employing sea water resulted in the loss of about 0.5% of the total activity over a period of 13 days. In both cases a major fraction of the total activity released was detected within the first 24 hr. Thus, after a preliminary leaching, the spheres may be considered to be inert with respect to loss of activity by subsequent leaching.

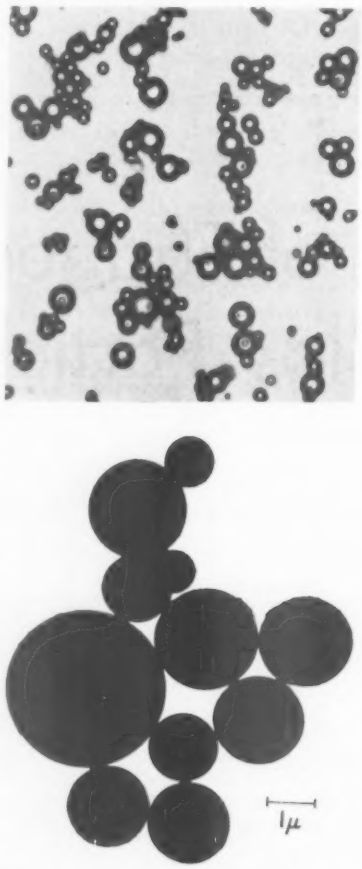


FIG. 2. Range of bead sizes as shown by (top) optical (½ in. ≅ 10μ) and (bottom) electron microscope photographs

Radiation Characteristics

The preparation and use of spherical radiation sources in medical research has recently been described. Styrene-divinylbenzene copolymer beads containing I^{131} were prepared and utilized in a study of myocardial shock produced by coronary occlusion (*2*). Radioactive glass beads were made by fusing an active salt with powdered glass in a micro furnace (*3*). The resulting beads, 50–1,000 microns in diameter, were hand-sorted under a microscope to obtain spherical ones of a given diameter.

As radiation sources for experimental or therapeutic uses, spheres prepared by the method developed in this laboratory possess a number of advantages. Physically, the particles are of uniform shape, and the size range is relatively narrow. The range can be even further reduced by means of a simple settling classification step.

The radiation dose rate in the vicinity of a particle can be readily calculated from the geometrical size, shape, specific activity and density. The average specific activity of the beads may be determined by completely dissolving a weighed sample in an H_2SO_4-HF mixture and counting an aliquot of the solution. The radiation characteristics of the beads can be varied over a wide field and depend only on the radioisotopes chosen for

the exchange step. These, in turn, are limited to nuclides which form cations stable in aqueous solutions. Thus, it is possible to standardize the physical features of the source and vary the half-life, the type of radiation, energy of radiation, and specific activity.

Methods of activation. In general, two methods could be employed for making the active spheres. In the first, the inactive element would be introduced into the clay, the spheroidizing process carried out, and the spheres irradiated in a nuclear reactor to produce the desired nuclide. Activities induced in the elements of the clay mineral by (n,γ) reactions are either very short-lived or of insignificant magnitude.

The second method consists of introducing the radioactive element, either a fission product or an irradiated nuclide, into the mineral followed by the spheroidizing treatment.

In the table below is a partial list of elements which would be chemically suitable for incorporation into montmorillonite. Included are estimated values of attainable specific activities. Of the elements listed, Ce^{144}-Pr^{144} and Sr^{90}-Y^{90} have actually been incorporated into clay spheres. Aged mixed-fission products have also been used successfully.

Possible Applications

The chemical stability, non-toxicity, and ease of production of the clay spheres suggest a number of applications to various fields of research. As inert insoluble tracers, the spheres could be used to follow the movements of fine particles through aqueous or gaseous systems. Since the particles can be obtained within a fairly narrow size range, their ballistic or hydrodynamic properties could be readily determined. For the irradiation of liquids or gases a porous sintered source could be fabricated, or a fluidized bed of particles could be employed. A sintered source has been made by heating a quartz tube containing a close-fitting plug of spheres to 850° C for 24 hr. The spheres sintered together and also to the quartz tube.

In medical or biological applications, the disadvantages of using radioactive salts, which may be toxic or which may not remain localized due to excessive solubility, could be overcome by the use of the clay beads. The filtering action of any of a number of specific organs may be utilized to concentrate the spheres yielding an internal radiation source. By properly choosing the radiation of the radioactive nuclide, say, a low-energy pure beta emitter, radiation damage may be confined within predictable limits. Direct implantation of a clay sphere at a particular location possibly may be used to irradiate an individual group of cells without damaging surrounding tissues.*

The method of sphere production is in itself applicable to other substances of suitable melting point; e.g., aluminum oxide spheres have been prepared. The final particle size may be altered by adjustment of several parameters such as flame size, oxygen velocity, original particle size and torch dimensions. However, no investigations have been carried out along these lines.

Specific Activity of Beads Activated by Irradiation or with Fission Products

Nuclide	Specific activity of beads*: Fission product† (c/gm)	Specific activity of beads*: Irradiation isotope‡ (mc/gm)	Irradiation time (days)	Other activities produced on irradiation	Remarks
Cu^{64}	—	96.7	3	Cu^{66}, 4 m	
Zn^{69}	—	5.3	3	Zn^{65}, 250 d	
Ga^{72}	—	29.2	3	Ga^{70}, 20 m	
Na^{24}	—	37.4	3	None	
Pr^{142}	—	272	4	None	
Rb^{86}	—	31.8	4	None	
La^{140}	2.6×10^4	175	8	None	CF daughter of Ba^{140}
Y^{90}	1.7×10^4	26.1	13	None	CF daughter of Sr^{90}
Au^{198}	—	2,010	13	None	
Ba^{140}	14.9§	—	—	—	
Pr^{143}	20.4§	—	—	—	
Sr^{89}	2.2×10^2§	0.074	60	None	
Y^{91}	2.3×10^2§	—	—	—	
Ca^{45}	—	0.20	150	—	0.46 mc/gm‖
Zn^{65}	—	2.69	150	Zn^{69}, 14 h	6.6 mc/gm‖
Ce^{144}	123§	—	—	—	
Pr^{144}	—	—	—	—	In equilib. with parent Ce^{144}
Cs^{134}	—	194	150	None	268 mc/gm‖
Tl^{204}	—	143	150	None	
Pm^{147}	29.7	—	—	—	
Co^{60}	—	6.4	150	None	
Sr^{90}	8.9	—	—	—	
Cs^{137}	10.8	—	—	—	
Ni^{63}	—	0.22	365	Ni^{65}, 2.6 h	0.8 mc/gm‖

* Assuming exchange capacity of 1 milliequivalent of cation per gram of clay. Values based on β-energy of parent only (4). Lower levels may be obtained by carrier dilution.

† Assuming carrier-free nuclide. Actual capacities may be from 1–50% of values given, except Y^{90} and Pm^{147} which are obtainable carrier-free (CF).

‡ Irradiation in BNL reactor flux of 4×10^{12} n/cm²/sec.

§ 100 days cooling before separation.

‖ Specific activity attainable with ORNL processed radioisotopes (U. S. AEC Isotopes Catalogue No. 4, 1951).

The authors wish to thank Dr. L. F. Nims of the Biology Department of BNL, and Mr. R. F. Smith for preparing, respectively, the electron and optical photomicrographs. The montmorillonite was kindly furnished by the Filtrol Corp., 727 W. 7th St., Los Angeles, Calif.

* * *

BIBLIOGRAPHY

1. R. E. Grim, W. F. Bradley, *J. Am. Ceram. Soc.* **23,** 242 (1940)
2. M. Tubis, H. I. Jacobs, NUCLEONICS **10,** No. 9, 54 (1952)
3. W. Kisielski, G. Svihla, A. M. Brues, *Science* **112,** 400 (1950)
4. Circular NBS-499 (National Bureau of Standards, U. S. Department of Commerce, Washington, D. C., 1950)

* Work along this line is being done at BNL by Dr. J. Gennaro.

FIG. 1. Section of interlocking concrete block wall. T-shaped blocks have been laid without mortar. Square blocks like those shown at left of T-block are not needed for square-cornered walls

Interlocking Concrete and Lead Blocks for Radiation Shielding

By CLARK GOODMAN and GARDNER A. NORTON*
Massachusetts Institute of Technology
Cambridge, Massachusetts

Interlocking blocks of concrete or lead can be used for temporary or permanent radiation shields in research laboratories. A joint project of the Nuclear Shielding Group and the Building Materials Research Laboratory at MIT has investigated the interlocking block originally designed by F. Forrest Pease.† It is a hollow, T-shaped concrete block averaging about 45% concrete and 55% void by volume. The blocks interlock in three dimensions when laid up into a shielding wall as shown in Fig. 1. Two views of a single block and some suggested wall arrays are shown in Fig. 2.

Fabrication

The first batch of concrete blocks was made in a hand-operated steel mold box (Fig. 3) that stripped upward, as shown in Fig. 4, producing the

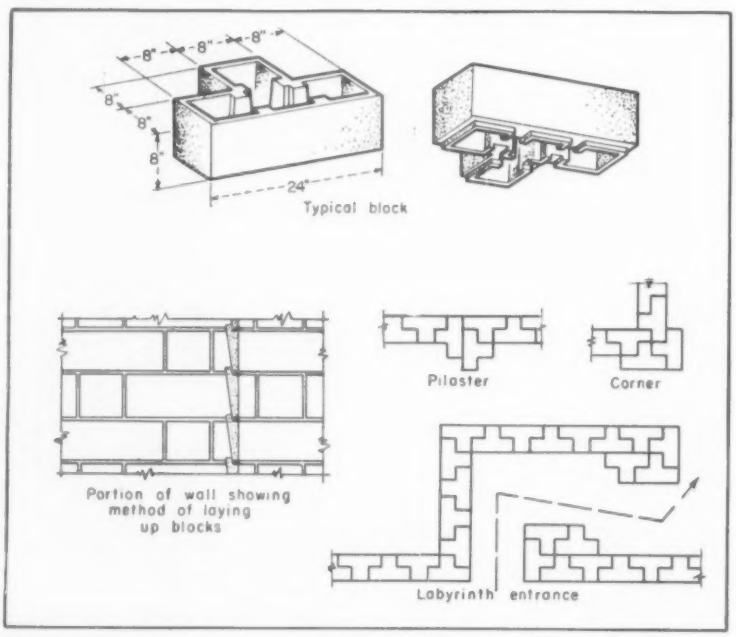


FIG. 2. Diagrams of typical concrete block, wall construction, wall assemblies

* PRESENT ADDRESS: Museum of Science, Boston, Mass.

† ADDRESS: 66 Bellevue Road, Squantum, Mass.

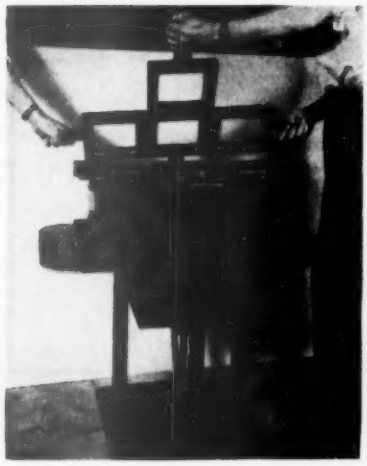


FIG. 3. Mold box for concrete blocks. Operators hold chamfered pallet

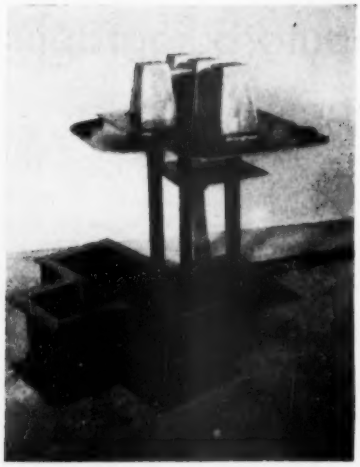


FIG. 4. Steel plate inside mold is shown in raised position used for stripping block

FIG. 5. Finished interlocking block being stripped from mold

block as shown in Fig. 5. Each block after being poured was rodded by hand and tamped down before stripping.

It was necessary to insert small wire reinforcing stirrups through the bridges or "keys" of the block to prevent sagging during curing, which was done at controlled temperature and humidity. When these bridges were thus reinforced, a strong block was made that retained its shape through normal handling.

The blocks were $8 \times 16 \times 24$ in. in size, having twice the cubage of an ordinary concrete block. This is not necessarily the optimum size, but the results obtained make it clear that other sizes could be fabricated without undue modification of our methods. The blocks could have three partitions or inner walls for increased strength, this being the original form as designed by Pease.

Quantity production. The block-molding machine was later transferred to the plant of Anthony Corrado, Inc., in Providence, R. I., where blocks were made under normal commercial practice. By using the reinforced bridge we had developed, they obtained a very satisfactory product. The same mold was used with hand rodding eliminated in favor of a commercial vibrating process for concrete or cinder blocks. Vibrated blocks have smoother surfaces and better fit.

As a result of this study, we believe that these blocks have definite commercial possibilities. But the mold for manufacture in quantity should be redesigned so that the blocks could be cast in an inverted position. The blocks would be cast individually on a standard vibrating machine and stripped downward, rather than stripped upward.

Rates of production are estimated by the trade as being about 1,600 per day per machine per 8-hour operating shift, with only one block at a time from a single mold. Undoubtedly a multiple mold box could be designed to provide for multiple pouring and vibrating.

The unit cost of building a wall with these blocks would be comparable to that with standard solid concrete blocks. Savings of skilled labor in laying up such a wall tend to offset the increased cost per unit block, as no mortar is required.

Small lead blocks. A small-scale mold was fabricated from which a number of lead blocks of the same interlocking type were cast. These $2 \times 4 \times 6$ in. blocks can be made solid or, as in our case, hollow and filled with lead shot for additional shielding.

Special Features

One feature of interest to research laboratories is that walls of these interlocking concrete blocks are not only easily constructed but also easily removed and relocated as necessary. Flexibility of walls is another feature when heights do not exceed 15 ft. Also, labyrinths are easily made.

A T-shaped block $8 \times 8 \times 24$ in. weighs 90 lb; two men are needed to place it in position. Despite this, a wall can be placed quite readily. The thickness of a single wall is dictated by the height of the T. Multiples of this thickness (double or triple) can be built that interlock laterally.

Estimates of wall thickness required may be made on the basis of previous measurements for concrete walls (*1*). The transmission of cracks in such a wall is of minor importance as indicated by radiation surveys on a cyclotron shield (*2*).

Possible applications of these blocks to civilian defense have been discussed elsewhere (*3*).

Added shielding. The hollow walls formed by the concrete blocks can be filled from the top with a variety of fills to provide additional shielding. The type of fill used depends upon whether gamma rays or neutrons are of chief concern. High water content fills, with either bound or free water, can be used to attenuate neutrons. Lime putties or concrete slurries have been suggested. Ores high in metallic content and water content (such as limonite) could be used for a composite neutron-gamma shield.

* * *

Only one mold has been made for concrete interlocking blocks, but we would be glad to lend it to any laboratory for experimental use or to any manufacturer.

BIBLIOGRAPHY

1. V. Delano, C. Goodman, *J. Applied Phys.* **21,** 1040 (1950); E. Creutz, K. Downs, *ibid.* **20,** 1236 (1949); P. C. Gugelot, M. G. White, *Phys. Rev.* **74,** 1215 (1948)
2. J. W. Crawford, E. E. Kintner, C. Goodman, MIT Technical Report 38 (Laboratory for Nuclear Science and Engineering, Sept. 27, 1950)
3. J. A. Murray, C. Goodman, G. A. Norton, *Pit and Quarry* (Concrete Products Section, Oct. 1, 1951)

Preparation of Microautoradiographs with the Use of Stripping Film

By W. E. LOTZ and P. M. JOHNSTON*
University of Tennessee—Atomic Energy Commission Agricultural Research Program
Oak Ridge, Tennessee

A simple modification of the reported stripping film techniques has been found of particular advantage. When microscopic autoradiographs are made, employing the stripping film techniques described by Pele (*1*), Berriman *et al.* (*2*), and Herz (*3*), the emulsion has a tendency to pull unevenly from the tissue during exposure or slip entirely off the slide during processing in the photographic solutions or wash. This results in the complete loss of many autoradiographs or loss of superimposition of the film and tissue.

These losses are prevented by the modification of technique described here. An additional advantage is that it is not necessary to coat the glass slides with gelatin, which not only saves time but also facilitates the utilization of Belanger's (*4*) inversion method.

The improvement is accomplished simply by using a strip of emulsion long enough to wrap completely around the breadth of the slide, enabling the two ends to overlap at least one-half inch, Fig. 1. Because of the adhesive properties of the stripping film, a very tight and permanent bond that does not loosen during exposure or processing is formed by the overlap.

When the emulsion is once in position it remains in constant register. This is of particular importance for interpretation of the resulting autoradiographic image with respect to the localization of the radioactivity in the cell or tissue.

Technique

Sections are prepared by appropriate histological methods and after sectioning are mounted on clean glass slides without water flotation. This lessens leaching of the radioactivity from the tissue. When paraffin is used, the slides are placed in an oven at 54 to 56° C until the paraffin surrounding the tissue is melted and the tissue spreads. The slides are dried for two to three hours in dust-free boxes, and after drying, are deparaffinized in two changes of xylol and then passed into dioxane where they are left until covered with emulsion. As reported by Holt *et al.* (*5*), dioxane has been found to leach less radioactivity from tissue sections than alcohol or other hydrating and dehydrating agents.

Under prescribed safelight conditions, strips of emulsion three inches in length and of sufficient width to cover the tissue sections are cut and floated on water for three to four minutes. The slide bearing the section is brought up underneath the emulsion by alternately tipping the slide from side to side as the emulsion is lifted from the surface of the water, Fig. 1.

The slides with the emulsion in place are suspended in a vertical position and allowed to dry in a dust-free darkroom or cabinet for two to three hours. They are then placed in a slide box containing a drying agent, sealed with masking tape, and put in a refrigerator for exposure.

After the proper duration of exposure the slides are developed, fixed and washed. Upon the completion of the washing, the overlapping emulsion is removed by carefully scraping the emulsion at the edges of each side of the top surface of the slide with a flat spatula (Fig. 2). The slides are placed in a horizontal position to dry.

If desired, the autoradiograph may be inverted at this point simply by returning the slide to water, thus causing the emulsion with adhering tissue section to float free. It has been found that, almost without exception, the section will adhere to the emulsion. The emulsion is then remounted with the section uppermost.

When the tissue under the emulsion is to be stained, the overlap is left in place during staining and mounting.

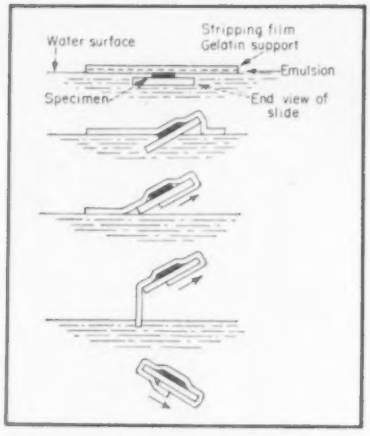


FIG. 1. Application of stripping emulsion to specimen with formation of overlap

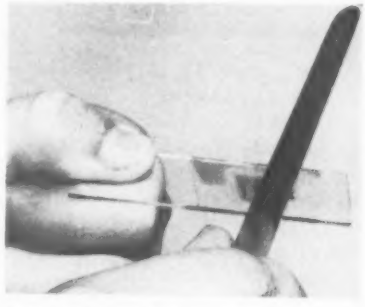


FIG. 2. Removal of overlap

The tissue may be stained directly through the emulsion by routine methods or by pipetting the stain on to the emulsion either before or after drying. The autoradiograph is passed through an alcohol-xylol series and then mounted or is air dried and then placed in xylol before mounting.

If the section has been inverted, it is preferable to pipette the stain and xylol on to the tissue.

This technique may be used with either the Kodak Limited Autoradiographic Stripping Plate or the Eastman Kodak Company 35-mm Permeable Base Stripping Emulsion.

* * *

The authors wish to express their appreciation to Dr. C. L. Comar for his help in the preparation of this article and to Joseph Houston for the photography. This article is published with the approval of the Director of the Tennessee Agricultural Experiment Station. Radioactive materials were obtained on allocation from the U. S. Atomic Energy Commission.

BIBLIOGRAPHY

1. S. R. Pele, *Nature* **160,** 749 (1947)
2. R. W. Berriman, R. H. Herz, G. W. W. Stevens, *Brit. J. Radiol.* **23,** 472 (1950)
3. R. H. Herz, NUCLEONICS **9,** No. 3, 23 (1951)
4. L. F. Belanger, *Anat. Record* **107,** 149 (1950)
5. M. W. Holt, R. W. Cowing, S. Warren, *Science* **110,** 328 (1949)

* Oak Ridge Institute of Nuclear Studies Fellow for the University of Arkansas.

Centralized Control by Honeywell

speeds nuclear research

Centralized control, engineered and built by Honeywell, can contribute a great deal to your research or production project. First, it will save you many valuable man-hours—because you'll have the benefit of Honeywell's panel engineering service, working in close cooperation with your own staff to develop a convenient efficient design.

Second, you'll gain by Honeywell's application engineering, which aids in the selection of the right instrument and control for each phase of process operation. Notable among the measuring "tools" available are the many modifications of the versatile *ElectroniK* potentiometer, which are readily applicable to numerous measurements involved in nuclear reactors.

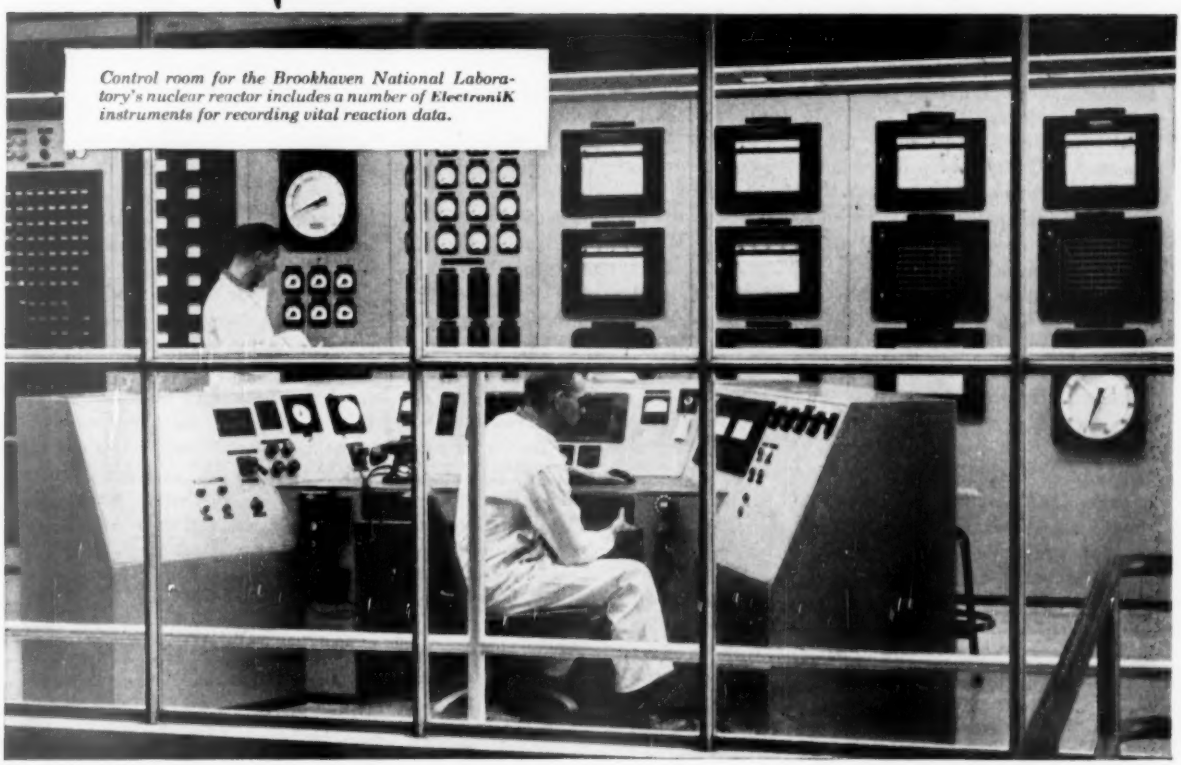
And finally, you'll profit by Honeywell's undivided responsibility for the completed panel or system. As made by Honeywell, each board is completely assembled in a manufacturing department devoted exclusively to panel assembly. All instruments, switches, back-of-panel wiring and piping are mounted and connected. The finished panel arrives ready for connection to your own equipment.

Your local Honeywell engineering representative will be glad to discuss your panel requirements—and he's as near as your phone.

MINNEAPOLIS-HONEYWELL REGULATOR CO., *Industrial Division*, 4571 Wayne Ave., Philadelphia 44, Pa.

● **REFERENCE DATA:** Write for Bulletin No. 85-20, "Centralized Instrumentation . . . Unlimited."

MINNEAPOLIS
Honeywell
BROWN INSTRUMENTS
First in Controls



Control room for the Brookhaven National Laboratory's nuclear reactor includes a number of ElectroniK instruments for recording vital reaction data.

Special Equipment for C^{14} Work

By B. M. TOLBERT, N. GARDEN, and P. T. ADAMS
Radiation Laboratory and Department of Chemistry
University of California, Berkeley, California

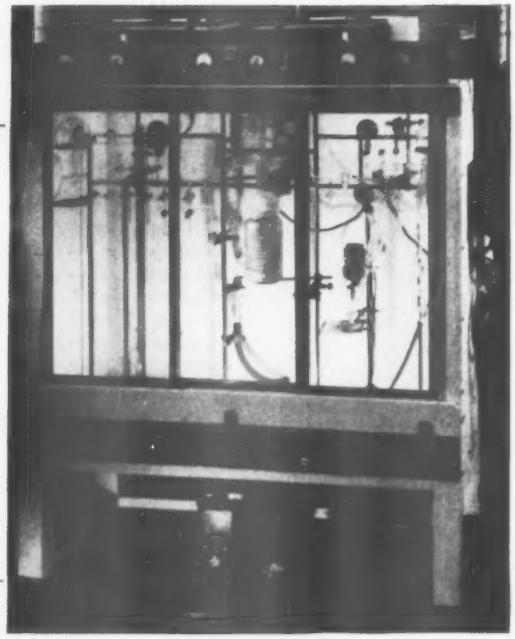


FIG. 1. Enclosure for vacuum apparatus

Two pieces of equipment have been designed for the laboratory in which large amounts of carbon-14 are handled. One of these, a vented housing for a vacuum manifold, protects the chemist against ingestion of large amounts of radioactivity. The other, a hooded cleaning area, makes possible a safe, thorough, and reproducible decontamination procedure.

Although the health hazards due to ingestion of C^{14} have been shown in the last several years to be far less than was first anticipated (*1–6*), there is, nonetheless, need for great care in handling this radioactive element to avoid unnecessary ingestion and contamination. The probability of ingesting appreciable quantities of solid radioactive organic compounds, such as amino acids, fatty acid salts, and drugs has not proved a serious problem in practice. Checks of the personnel of the Bio-Organic Chemistry Group of the Radiation Laboratory have shown no detectable C^{14} in blood samples within the sensitivity of the assay techniques, ± 0.01 dpm/mg $BaCO_3$ (*7, 8*).

The chances for ingestion are much greater in the case of the volatile organic compounds, such as lower-molecular-weight halides, alcohols and hydrocarbons. These compounds are usually handled in a glass vacuum system (*9*), and there is a fairly high probability that a system may be broken at a critical moment, or that gaseous pressure can unseat a stopcock or joint due to unforeseen reactions or wrong manipulations.

Vacuum-Line Box

To provide more adequate protection for the chemist in such cases, a movable box, large enough for a standard vacuum line, has been designed; it is shown in Fig. 1. This unit consists of a wooden box 5 ft wide, 4 ft high, and 2 ft deep, which is mounted on a base frame and four large (5 in.) casters. Three safety-glass doors are hung on two tracks by small ball bearings. The two doors on the front track may be removed, after releasing a safety catch, by rolling the door off the end of the track. This provides easy access to the box for construction of equipment.

Outlets are provided in the side of the box for standard utilities such as gas, water, vacuum, etc. On the right side of the box is a small control panel containing switches for lights, fan, accessories and a stirrer-motor rheostat. A master switch controls all accessories except the fan switch, which is put on a separate circuit. The mechanical vacuum pump is placed on the floor beneath the box to reduce noise and vibration, but it is vented inside the enclosed area for protection.

The floor of the box is completely covered by a steel tray, coated with a plastic paint.* The tray may be removed for decontamination through the piano-hinge panel on the lower front of the box. This panel, which holds one-half inch mat of Owens-Corning Aircraft Insulating fiberglass, Type PF105, also acts as a filtered air inlet for the box.

In operation, the sliding doors remain closed between the operator and the glass equipment except for small slits opened for the manipulation of dewar flasks, stopcocks, etc. A fan, mounted on top of the box, exhausts filtered air through three openings in the upper back wall at a rate of 85 ft^3/min. The air discharge may be made into a hood duct system or outside of the building proper through a window. The discharge filters are specially constructed units which provide four boxes (1 ft^2 each) of PF105 filter medium, with a low pressure drop across them.

Three thermocouple vacuum gage

* Drum lining laquer, Plastic Paint 4A, Interchemical Corp., San Francisco, Cal. The material is a phenol-formaldehyde resin cured by baking at 375–400° F. It is very resistant to acid and organic solvent.

Available NOW

Tracerlab's SU-8 Pocket Dosimeter (0-100 mr) is a highly accurate, self-reading, cumulative-type dosimeter. It need not be discharged to be read, and the wearer may determine exposure at any time simply by looking into the instrument. A simple charging device returns the scale fiber indicator to zero. The SU-8 is less than 30% energy dependent between 70 KV and 1 MEV; has an accuracy of ±5% full scale. Electrical leakage of the SU-8 is less than 2 mr/day; linearity is 10% on a voltage basis. A magnetically operated charging contact, sealed in the assembly, is spring loaded to prevent accidental discharge. This outstanding instrument was designed in accordance with Argonne National Laboratory specifications.

Price . . . . f.o.b. Boston, $47.50

●

Chicago, New York, Washington, Houston, Paris

Tracerlab® INC.
130 HIGH ST., BOSTON
2295 SAN PABLO AVE., BERKELEY

Los Angeles

Want more information? Use post card on last page.

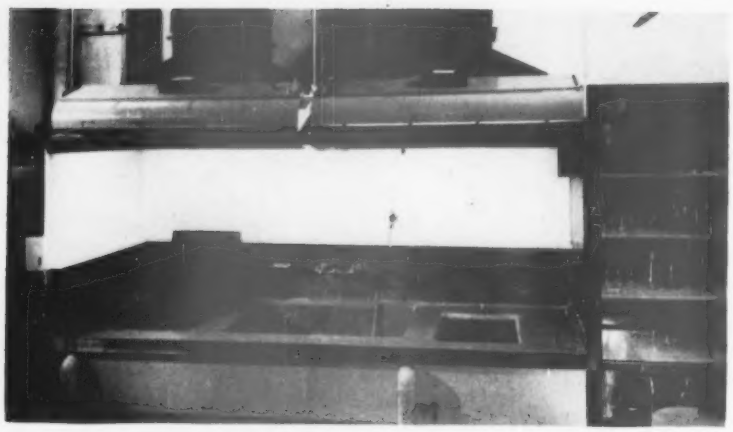


FIG. 2. Decontamination sink and hood

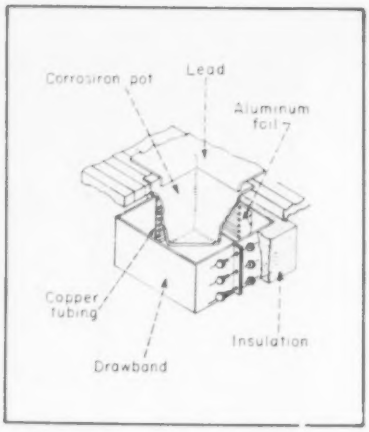


FIG. 3. Detail of cleaning-solution pot in decontamination sink

power packs are mounted at the top front of the box in Fig. 1.

This type of portable vacuum line box has proved very useful in service and is certainly recommended for use with 50–150 mc of volatile radioactive compounds of C^{14}, H^3, and S^{35}. If the unit is extensively contaminated, it may be easily removed from the laboratory for cleaning.

Cleaning of Glassware

High-level activity C^{14} synthesis presents a problem when carried out in the same general area as biological and chemical studies which may use only tracer amounts of activity. Cross contamination can completely mask the results of experiments in which some samples should be free from activity, and can lead to erratic results in radioactivity balances. Although complete separation of glassware and work areas would be desirable, this is often not possible because of lack of space and equipment.

One of the most important causes of severe cross contamination in a C^{14} radiochemical laboratory is incompletely cleaned glassware. Unless a hot cleaning solution is used, one cannot be sure that all organic material is removed from the glassware. However, it is necessary to make sure that vapors from the cleaning pots, hot water in the sink, etc., do not offer opportunities for ingestion of volatile radioactive residues or carbon dioxide. The use of carbon tetrachloride in degreasing stopcocks is also hazardous, and provision for removal of vapors should be made.

To solve these several problems, a dishwashing area has been constructed; it is shown in Fig. 2. The unit consists of a large lead-lined sink (36 by 20 in. by 10 in. deep), a stainless-steel detergent bath and a silicon-bearing iron* cleaning solution bath, all covered by a double canopy hood with sides but no front doors. The table and splash back are covered with $\frac{1}{16}$-in. lead sheeting. This gives good resistance to the corrosive action of the cleaning solution, and the slightly resilient surface decreases glass breakage. The upper sides of the hood area are covered with white plastic material† mounted on plywood.

Both the stainless-steel pot and the silicon-iron pot are heated by steam jacket as shown in Fig. 3. Low-pressure steam is used so that the maximum temperature is not more than 100° C. The stainless-steel pot is soldered directly to the lead sink top so no leakage can occur. The silicon-iron pot, however, merely has a cover of lead sheeting folded over the edge. The down spout in the bottom of this sink is sealed in with acid-proof cement.‡

The glassware drying cabinet, which is located to the right of the hood and serves as the right side partition, vents into the hood area. Two small steam radiators, placed on their side, serve as a source of warm air. This all-metal unit is painted with the Interchemical plastic paint 4A.

The hood system draws a total of 1,150 ft^3/min of air across the opening of the sink (3 by $8\frac{1}{2}$ ft). This gives sufficient air velocity to allow the worker to handle noxious chemicals or to stand directly in front of the hot cleaning solution bath without hazard or discomfort.

In operation, glassware is rinsed in running water and allowed to stand in the hot sodium phosphate-detergent solution for an hour. The glassware is then rinsed again, allowed to drain, and placed in the sulfuric acid-sodium dichromate cleaning solution (approximately 80° C) for 2–3 hr. The cleaning solution is freshly prepared every 3 to 4 weeks and is periodically strengthened by addition of about 9 lb of 30% fuming sulfuric acid per week.

After thorough rinsing with tap and distilled water, the glassware is dried. It has been found that glass equipment used in a 100-mc C^{14} synthesis retained no activity detectable with a thin-window G-M tube (<2 mg/cm^2 window thickness) after routine decontamination in this system.

* * *

The authors wish to acknowledge the extensive work on these projects and thank the members of the Health Chemistry Group, Radiation Laboratory, University of California. The work described in this article was sponsored by the U. S. Atomic Energy Commission.

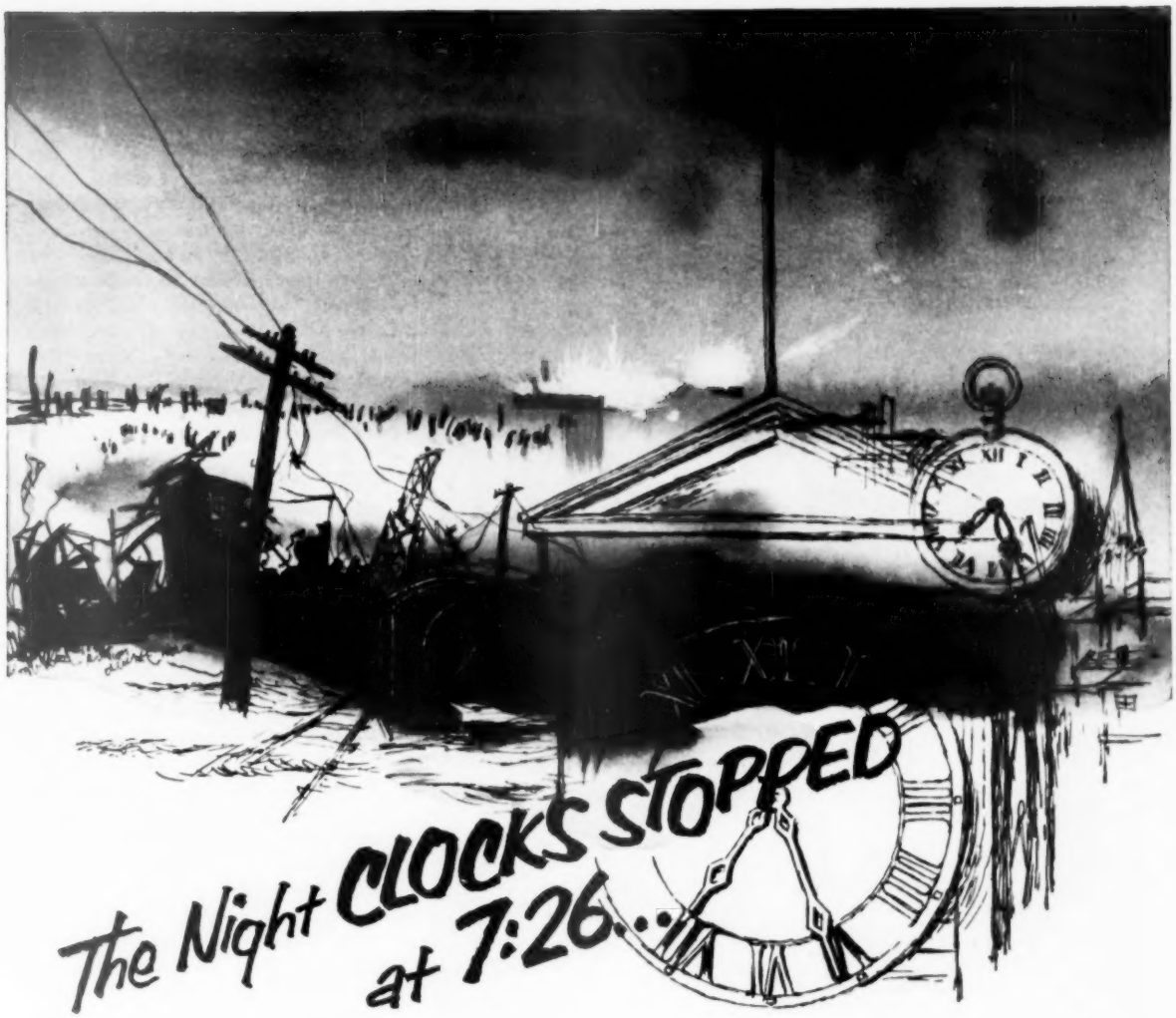
* Corrosiron sink with drain plug and standard down pipe. Pacific Foundry Company, San Francisco, California.

† Panelyte, St. Regis Paper Company, 230 Park Avenue, New York, New York.

‡ Penchor acid-proof cement. Pennsylvania Salt Manufacturing Company, Philadelphia, Pennsylvania.

BIBLIOGRAPHY

1. A. M. Brues, D. L. Buchanan, ANL-4787 (1952)
2. N. I. Berlin, B. M. Tolbert, J. H. Lawrence, *J. Clin. Invest.* **30,** 73 (1951)
3. N. I. Berlin, B. M. Tolbert, C. Lotz, *J. Clin. Invest.* **31,** 335 (1952)
4. G. L. Nardi, *Science* **111,** 362 (1950)
5. H. E. Skipper, L. White, Jr., C. E. Bryan, *J. Biol. Chem.* **180,** 187 (1949)
6. D. L. Buchanan, *J. Gen. Physiol.* **34,** 737 (1951)
7. B. M. Tolbert (to be published)
8. C. D. Janney, B. T. Moyer, *Rev. Sci. Instr.* **19,** 667 (1948)
9. M. Calvin *et al.*, "Isotopic Carbon," p. 127 ff. (John Wiley & Sons, Inc., New York, 1949)



Some 9,500 people were in South Amboy, N. J., that drizzly evening in 1950. At the waterfront, longshoremen were transferring the last of 12 freight cars of ammunition to lighters that would carry it to a waiting vessel in Raritan Bay.

But the City Hall clock never got to 7:27—and the freighter's deadly cargo never got loaded. Explosions shattered windows over a radius of 12 miles; and hundreds of people looked at their arms and legs and saw that flying daggers of glass had stabbed them.

At dawn, 312 of the injured had been counted.

★ ★ ★

Such disasters have happened many times before in America. They could happen again. And *if* they do—and *when* they do—there must be blood plasma on hand to take care of the injured. For blood saves lives!

But blood cannot be mined or manufactured. It must come from the veins of healthy men and women. Men and women who feel concern for a suffering neighbor. So give blood—now!

Whether your blood goes for Civil Defense needs, to a combat area, or to a local hospital—this priceless, painless gift will some day save an American life!

Give Blood Now

CALL YOUR RED CROSS TODAY!

National Blood Program

Business Executives!

✓Check These Questions!

If you can answer "yes" to most of them, you—and your company—are doing a needed job for the National Blood Program.

- ☐ Have you given your employees time off to make blood donations?
- ☐ Do you have a Blood Donor Honor Roll in your company?
- ☐ Have you set up a list of volunteers so that efficient plans can be made for scheduling donors?
- ☐ Have you arranged to have a Bloodmobile make regular visits?
- ☐ Has your management endorsed the local Blood Donor Program?
- ☐ Have you informed employees of your company's plan of co-operation?
- ☐ Was this information given through Plant Bulletin or House Magazine?
- ☐ Has your company given any recognition to donors?
- ☐ Have you conducted a Donor Pledge Campaign in your company?

Remember, as long as a *single* pint of blood may mean the difference between life and death for *any* American . . . the need for blood is *urgent!*

Intracavity and Interstitial Administration

By J. E. STAPLETON* and W. J. WINGO
Departments of Radiology and Biochemistry, The University of Texas M. D. Anderson Hospital for Cancer Research, Houston, Texas

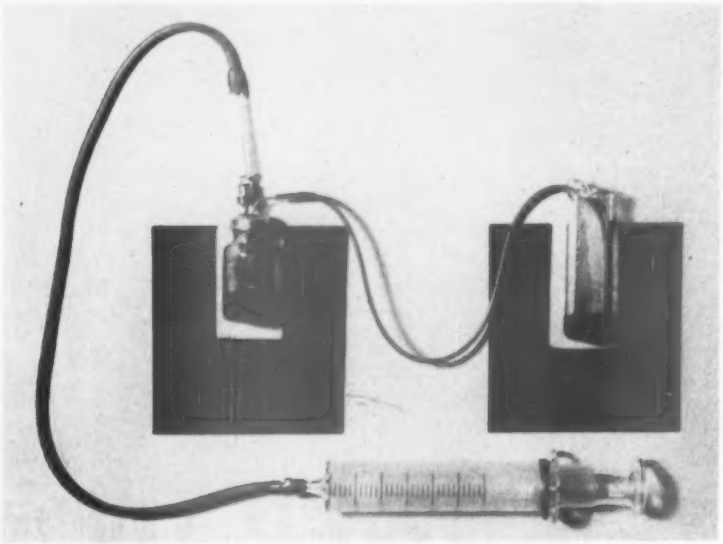


FIG. 1. Apparatus used to remove radioactive gold from shipping bottle. Black silhouettes simulate the lead shields

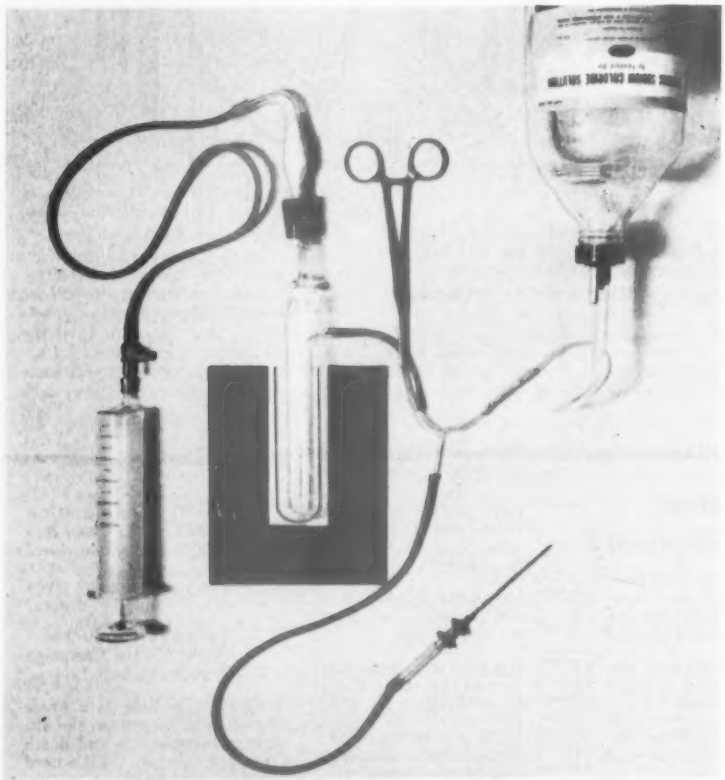


FIG. 2. Apparatus for intracavity instillation of radioactive gold solution. Black silhouette simulates lead shield

Radioactive colloidal gold-198 has been used for some time in this hospital, both for intracavity instillation and for direct infiltration of prostatic tumors. Methods for dispensing and using this material have been developed that effectively reduce the exposure of personnel while requiring relatively little special apparatus. The writers believe that these methods are superior to those previously described and present them here for that reason.

Removal from Shipping Bottle

The radioactive gold sol is received from Abbott Laboratories in the usual vaccine bottle. This bottle is removed from the shipping container, and the radioactivity of its contents checked by means of a Lauritzen electroscope. The bottle is next placed in a close-fitting lead shield (wall thickness 1¼ in.). In an adjacent lead shield is placed a small beaker (about 1 in. in diameter and 2½ in. tall) to the rim of which is fused a bent glass rod (Fig. 1). This beaker, like all glassware, tubing and instruments used in dispensing, is autoclaved before use, and sterile technique is used throughout the procedures.

The aluminum protector for the rubber cap of the bottle containing the radioactive gold sol is removed with a hemostat, and the rubber cap is swabbed with alcohol. A short (¾ in.) No. 25 hypodermic needle, connected to a 20-ml syringe by a glass adapter and a length of rubber tubing, is inserted in the rubber cap of the gold bottle; this serves to vent the pressure in the gold bottle. A pair of ordinary utility pliers is a convenient tool for holding the needle.

A special needle is used for the actual removal of the gold. This is made by removing the hub from a 3½-in. No. 17 needle and bending the upper inch of the shaft through a right angle; the point of the needle is reground to have a short bevel. A No. 8 catheter with the eye and flared end removed fits this needle exactly. The free end of the catheter is placed in the small beaker, and is kept from slipping out by the curved glass rod attached to the beaker's rim. The needle is now thrust through the cap of the vaccine bottle so that its tip reaches the bottom

* Bertner fellow for cancer research.

of the bottle near its edge. The gold sol is forced into the beaker by air pressure from the syringe.

Intracavity Instillation

The apparatus employed for the intracavity instillation of Au^{198} sol is shown in Fig. 2. The infusion flask is a modification of the apparatus of Tabern *et al.* (*1*) but is simpler to use and easier to charge with gold. An 18-in. piece of rubber tubing is fitted to the delivery tube of the infusion flask before sterilization. The flask is placed in its shield next to the beaker containing the gold sol, and the requisite amount of sol transferred volumetrically from the beaker into the dispensing flask by a pipette controlled by a Tracerlab remote pipetting apparatus. The stopper, carrying an air filter, rubber tube, and three-way stopcock for a syringe, is inserted in the neck of the infusion flask, and the shield with its contents is carried to the patient's bedside.

Paracentesis abdominis/thoracis is performed using a cannula which has the butt shaped to accept the male end of a glass adapter. After the fluid is withdrawn, the cannula is connected to one end of a Y tube by an adapter and a rubber tube. The other ends of the Y tube are respectively connected to the infusion flask and (by means of a Venopak outfit) to a bottle of sterile normal saline.

A hemostat is placed on the tube between the Y and the infusion flask, and saline is allowed to run into the body cavity. When it is apparent that the saline infusion is going well, the hemostat is moved to the tube between the Y and the saline bottle, and the gold sol is injected into the patient's body cavity by air pressure. The infusion flask is then rinsed with saline, and the rinsings injected into the body cavity by appropriate manipulations of the syringe and hemostat.

Interstitial Injection

Dental syringes† charged by small glass capsules containing about 2.3 ml of fluid are used for interstitial injection since they are, compared to shielded syringes, small, light, and convenient to use, and since the user is exposed to the radiation of only about 7 mc of gold at one time. The beta radiation is much reduced by a 4-mm shield of transparent plastic slipped over the barrel of the syringe (Fig. 3).

The gold sol for use in the dental syringes is diluted in a flask like that used for the intracavity infusion. In this flask is placed 150 units of hyaluronidase, 0.5 ml of 1/1,000 adrenaline solution, and sufficient normal saline so

† The syringes, capsules and needles were made available through the courtesy of Cook-Waite Laboratories, Inc., New York, N. Y. The writers wish to record their gratitude for this help.

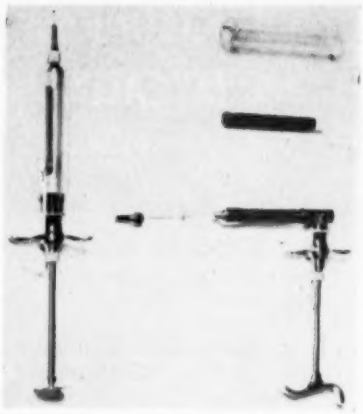


FIG. 3. Dental syringe, cartridge, and plastic cover for interstitial injection of radioactive gold. Shown disassembled above, assembled below

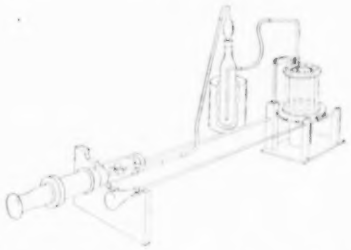


FIG. 4. Apparatus for filling dental syringe cartridges with radioactive gold. Lead shielding in front of apparatus not shown

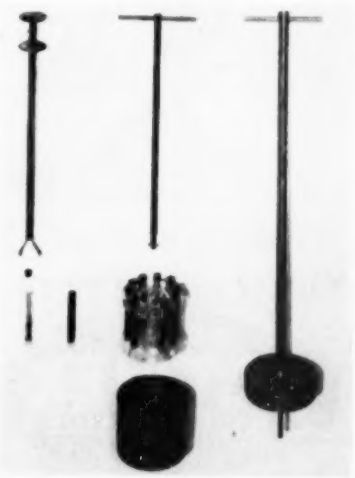


FIG. 5. Mechanic's pick-up tool with empty and filled syringe cartridge (left); transport shield, plastic capsule holder and tool for removing holder from shield (center); and cover and carrying handle for transport shield (right)

Average Exposures Recorded For Various Procedures (mr)

Procedure	*Intraperitoneal instillation* (*Body*)	*Intrapleural instillation* (*Body*)	*Interstitial prostate injection* (*Hand*)	(*Body*)
Preparation of isotope	8.5	15		4
Preparation and administration of isotope	16	45		
Turning and nursing patient for 12 hours*	65	32.5		
Administration of isotope:				
Urologist			70	41.6
Radiotherapist (performing injection)			70	21
First assistant			152	64.6
Syringe nurse			36	50

* A special nurse is assigned to the patient to give ordinary nursing care and to turn the patient at 15-minute intervals for 2 hours after the dose is given, and at half-hour intervals for the next 10 hours. This insures even distribution of the Au^{198} in the cavity.

NEARLY EVERYBODY IN NUCLEONICS USES MYCALEX GLASS-BONDED MICA

But very few tell us what they do with it. So we want to ask you TWO QUESTIONS:

1. Are you getting all you should out of these Mycalex advantages?
   - No Distortion Under Pressure
   - High Temperature Distortion Point (650°F.)
   - Low Loss Factor
   - Corona Resistance—Does Not Carbonize
   - No Moisture Pick Up
   - Dimensional Stability
   - High Structural Strength
   - Holds Its Inserts tightly over a large temperature range.

2. DO YOU KNOW how readily you can MACHINE EXPERIMENTAL PARTS FROM MYCALEX 400?

WRITE for the full story

SINCE 1919 MYCALEX THE INSULATOR ®

MYCALEX CORPORATION of AMERICA

Owners of "MYCALEX" Patents and Trade-Marks

Executive Offices: 30 Rockefeller Plaza, New York 20, N.Y.

GENERAL OFFICES AND PLANT

118 CLIFTON BOULEVARD, CLIFTON, N.J.

that the total volume will be 23 ml when the desired amount of gold sol has been added (the average infiltration requires 14–17 ml). The specific activity of the final mixture is 3 mc/ml at the time of use.

The infusion flask (which stands in a lead shield) is charged with the radioactive solution and then stoppered with a rubber stopper carrying a cotton air filter and a long rubber tube. The side arm of the flask has been fitted with a short piece of rubber tubing connected to a bent glass spout.

A cylindrical plastic container, sterilized by soaking in Zephiran solution, and holding ten sterile capsules is placed on a remotely controlled indexing turntable behind a lead barrier. The base of the turntable carries a vertical rack and pinion on which the delivery spout from the flask is held by a clamp, so that the spout may be moved into or away from the open tops of the capsules. The indexing mechanism moves the capsules into place in turn beneath the delivery spout.

The shafts for the rack and pinion mechanism and the indexing head extend through holes in the lead barrier. The rack and pinion shaft terminates in a holder for a 20-ml syringe, to which the tube from the top of the dispensing vessel is connected by a three-way stopcock. See Fig. 4.

The contents of the flask are mixed by drawing air through the liquid by means of the syringe. The tip of the delivery tube is inserted into the mouth of a capsule by rotating the pinion, and gold sol is forced into the capsule by air pressure from the syringe. When the level of the sol in the capsule has been properly adjusted, the delivery tip is raised, another capsule is moved beneath it, and the process is repeated.

When all the capsules in the holder have been filled, the holder is placed behind a small lead shield and the stoppers fitted to the open ends of the capsules.

Each stopper, before sterilization, has been transfixed with a No. 25 hypodermic needle to serve as an air vent. A stopper is seized with a mechanic's pick-up tool, moistened with normal saline, and inserted into a capsule; once the whole periphery of the stopper has been entered in the capsule the pick-up tool is disengaged and used to press the stopper home and to hold it while the hypodermic needle is removed with a hemostat.

When all the capsules have been stoppered, the plastic holder is placed in a lead shield (Fig. 5) for transport to the operating theater.

Exposure of Personnel

Average radiation exposures of personnel in carrying out the procedures outlined above are given in the table. It is obvious that these small exposures compare favorable with others previously reported (*1*, *2*).

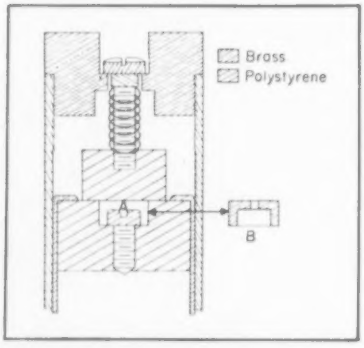
BIBLIOGRAPHY

1. D. L. Tabern, G. I. Gleason, R. G. Leitner, NUCLEONICS **10**, No. 2, 63 (1952)
2. M. Ter-Pogossian, A. I. Sherman, NUCLEONICS **10**, No. 3, 23 (1952)

An Improvement in the Victoreen 1,000-r Thimble Chamber

By C. S. SIMONS

Oak Ridge Institute of Nuclear Studies
Oak Ridge, Tennessee



MODIFICATION of thimble chamber to reduce error when used with high-energy gamma rays

Exposure of the entire length of Victoreen 1,000-r thimble chambers to a broad radiation field of high-energy gamma rays (greater than 1.0 Mev) has been found to produce readings about 1.4 to 1.5 times larger than that obtained with Victoreen 25-r and 100-r chambers under the same conditions. In an attempt to locate other sensitive points the top (thimble-end), middle, and bottom third of the 1,000-r cham-

ber were exposed successively to a narrow beam of gamma-rays from the ORINS cobalt-60 teletherapy unit. The chamber reading was observed for each exposure after which the chamber was recharged. The reading for the exposure of the top third, which was covered with a Lucite cap of 4 mm wall thickness to produce electronic equilibrium, was twice that for the bottom third.

This indicates that there is a sensitive region within the bottom third of the stem which can contribute up to 33% of the reading obtained when the entire chamber is exposed to a broad beam of high-energy radiation. This error is not evident in the manufacturer's calibration since the procedure involves only 40 and 100 kvp X-rays for which the brass cap is an adequate shield.

The ratio of two-to-one indicates that this lower sensitive volume must be about half the size of the thimble volume. Since the thimble volumes of the 25-r and 100-r chambers are respectively 40 and 10 times larger than the thimble volume of the 1,000-r chamber, one would expect that the lower sensitive volume would not contribute more than 1.2 and 4.8% respectively of the total dose indicated by these instruments if the size of the lower sensitive volume is the same in all three sizes of chamber.

It was assumed that this lower sensitive volume must be the air volume *A*, enclosed at the charging screw (Fig. 1). A brass plug, *B*, was machined to fill this volume. A small hole was drilled in the plug so that the air space formed by the slot in the screw could be filled by pouring melted ceresin wax into the hole.

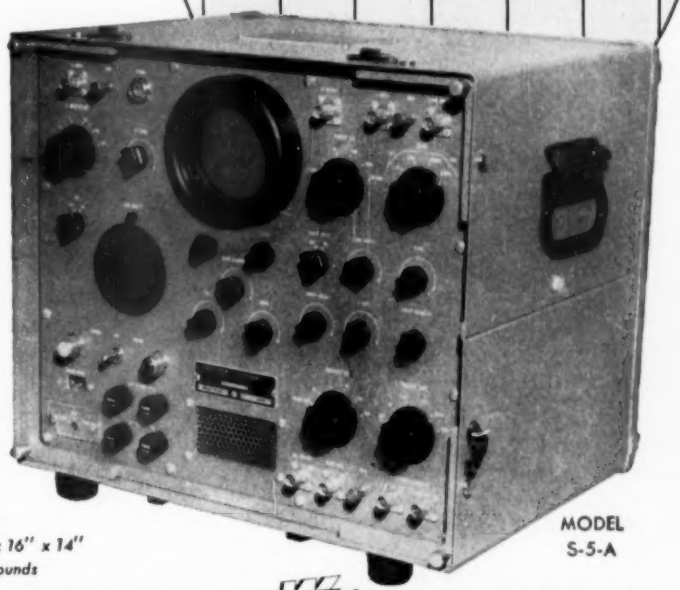
When the lower third of the improved 1,000-r chamber was later exposed to the cobalt unit, the readings were less than 3% of the top-third reading. The top-third was found to be identical in value with the reading obtained with a calibrated 100-r chamber placed at the same point.

TECHNICAL BRIEFS

● Goal of current ceramics research is to find a material for reactor construction that will withstand 3,500° F and still have desirable nuclear properties.

● Photomultipliers with lithium-antimony cathode have been developed by M. Schaetti, ETH, Zurich, Switzerland. Tubes have maximum response at 4,300 Angstroms, dark currents of 10^{-11} amp.

the Waterman LAB PULSESCOPE®



Size:
13" x 16" x 14"
60 Pounds

MODEL S-5-A

ANOTHER EXAMPLE OF Waterman PIONEERING...

The LAB PULSESCOPE, model S-5-A, is a compact, wide band laboratory oscilloscope for the study of all attributes of complex waveforms. The video amplifier response is up to 11 MC and provides an equivalent pulse rise time of 0.035 microseconds. Its 0.1 volt p to p/inch sensitivity and 0.55 microsecond fixed delay assure portrayal of the leading edge when the sweep is triggered by the displayed signal. An adjustable precision calibration voltage is incorporated. The sweep may be operated in either triggered or repetitive modes from 1.2 to 12,000 microseconds. Optional sweep expansion of 10 to 1 and built-in markers of 0.2, 1, 10, 100, and 500 microseconds, which are automatically synchronized with the sweep, extend time interpretations to a new dimension. Either polarity of the internally generated trigger voltage is available for synchronizing any associated test apparatus. Operation from 50 to 1000 c.p.s. at 115 volts widens the field application of the unit. These and countless additional features of the LAB PULSESCOPE make it a MUST for every electronic laboratory.

WATERMAN PRODUCTS CO., INC.
PHILADELPHIA 25, PA.
CABLE ADDRESS: POKETSCOPE

MEMO... Write for details today!

WATERMAN PRODUCTS

WATERMAN PRODUCTS INCLUDE

S-4-A SAR	PULSESCOPE
S-11-A INDUSTRIAL	POCKETSCOPE®
S-12-B JANized	RAKSCOPE®
S-14-A HIGH GAIN	POCKETSCOPE
S-14-B WIDE BAND	POCKETSCOPE
S-15-A TWIN TUBE	POCKETSCOPE

Also RAYONIC® Cathode Ray Tubes and Other Associated Equipment

BOOKS

Experimental Nucleonics

By ERNST BLEULER and GEORGE J. GOLDSMITH (Rinehart & Company, Inc., New York, 1952, xv + 393 pages, $6.50). Reviewed by GERHART FRIEDLANDER, Dept. of Chemistry, Brookhaven National Laboratory, Upton, N. Y.

Anyone who has faced the task of teaching a laboratory course in nuclear science—whether its name be "Nuclear Physics," "Nuclear Chemistry," or something else—should be profoundly grateful to Professors Bleuler and Goldsmith for the publication of their "Experimental Nucleonics." For here, in this reviewer's opinion, is the first really satisfactory laboratory manual published in this field.

To date, very few colleges indeed have offered laboratory courses in nuclear physics and chemistry. There are undoubtedly many reasons for this: Equipment for such courses is relatively expensive. The potential health hazard involved in the classroom use of radioactive materials has surely been a deterrent (although the amounts of radioactivity required for student experiments are actually fairly innocuous, as Bleuler and Goldsmith take pains to emphasize). Many will even question the desirability of including a laboratory course in so specialized a subject in the already crowded curriculum. However, one additional factor which has certainly delayed the teaching of the laboratory techniques of nucleonics in many universities has been the lack of an adequate laboratory manual, and this gap has now been filled. Thus, it is to be hoped that the publication of this book will stimulate the introduction of new courses or, where that is not considered feasible, at least the inclusion of some experiments on nuclear techniques in established laboratory courses in modern physics or physical chemistry.

The book is intended for students who have had "some prior training in the fundamentals of nuclear physics and in the fundamentals of chemistry." This reviewer believes that, in appropriate sequence, the experiments could be performed even in a laboratory course given concurrently with an introductory lecture course in nuclear physics or chemistry. Each experiment is preceded by a fairly detailed discussion of the ideas and principles involved. The study of these theoretical sections should complement, but not replace, a more systematic coverage of the fundamentals. At the end of each experiment, references are given both to standard works and to pertinent papers in the recent literature.

The book is divided into four parts: an introductory section and three groups of experiments entitled *General Techniques*, *Chemical Techniques*, and *Physical Techniques*.

The first of the introductory chapters deals concisely but quite adequately with the special problems connected with the handling of radioactive materials. It should serve to give the novice the proper respect for radiation and contamination hazards and some useful information on shielding and health-physics instruments without unduly alarming him about the dangers of work with radioactive sources. The second chapter is largely devoted to a discussion of Geiger-Müller counters, associated electronic circuits, and other accessories. One may perhaps question whether a useful purpose is served, in a book of this type, by the inclusion, without adequate discussion, of circuit diagrams for such standard commercially available items as discriminators, scalers, and high-voltage supplies. The third chapter contains some useful pointers on sample-mounting techniques and a few procedures for source preparations, the latter apparently intended for the instructor.

The group of nine experiments dealing with *General Techniques* ranges from an investigation of the properties and behavior of G-M counters through various experiments on relative and absolute beta counting, decay measurements, and simple radiochemical separations, to the determination of beta- and gamma-ray energies by absorption measurements. Also included is an experiment on the mean life of thermal neutrons in water which, to this reviewer, seems a little lengthy and involved at this stage of the game.

The section on *Chemical Techniques* contains another nine experiments including examples, on the whole well chosen, of radiochemical separations by solvent extraction, ion exchange, electrochemical methods, and coprecipitation, as well as illustrations of the Szilard-Chalmers and isomer separation techniques. Where an accelerator is available, the student will have an opportunity to learn typical target chemistry techniques by preparing carrier-free indium activity from deuteron-bombarded cadmium, and by determining the yield of F^{18} in a deuteron irradiation of water. The authors take cognizance of the special importance of C^{14} in tracer work by including an experiment dealing with the preparation of CO_2 samples containing C^{14} and the measurement of such samples in ionization chambers. The one example of a tracer investigation, the determination of the solubility of lead sulfate by means of S^{35} tracer, is perhaps not the most fortunate choice from the broad field of tracer applications.

The section on *Physical Techniques* consists of six experiments. The first deals with alpha-particle ranges and stopping powers; the next two illustrate the use of photographic emulsions and of scintillation counters, respectively. A lengthy experiment on various applications of coincidence techniques follows. The next exercise, in which the decay scheme of either Cu^{64} or Zn^{65} is determined, involves the use of an ingeniously simple home-made beta-ray spectrometer and an introduction to critical absorption measurements. The final experiment of the book consists of some cosmic-ray measurements by means of a simple counter telescope.

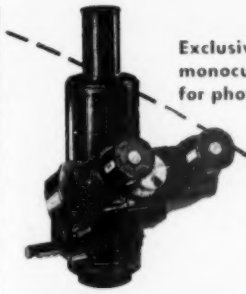
Selection of Experiments

The authors deserve a great deal of credit for having devised a series of experiments which acquaint the student with all the important instruments and techniques used in a modern nuclear laboratory. Clearly, not all of the experiments can be performed in a one-semester course; the authors state in the preface that they expect sixteen or seventeen of the twenty-four to be selected. The selection will, at least in part, have to depend on the availability of equipment. Most experiments can be performed with naturally occurring radioactive substances or with materials obtainable from the Atomic Energy Commission. Only two or three experiments depend on the use of accelerators. A few of the exercises, according to the authors, cannot be completed in a single laboratory period. The reviewer, without actually having performed the exercises, suspects that this is true for an even larger number of experiments.

It is particularly gratifying to the

nuclear chemist to find that the authors, though physicists, have recognized the need for the inclusion of a considerable number of radiochemical exercises in the book and, in the preface, recommend these for nuclear physics students as well as for students in other fields. Too many nuclear physicists are unfamiliar with the chemical techniques so useful in their field of research, and it would be nice if this deficiency could be avoided in the education of future generations of nuclear physicists. On the other hand, prospective nuclear chemists and students who wish to prepare themselves for tracer work will certainly profit greatly by performing a number of the more purely physical experiments outlined in the book.

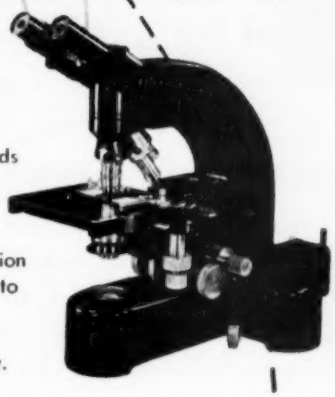
For the most part, the experiments are well chosen and their purposes and the principles involved are clearly and correctly explained. But occasionally ideas are stated in a misleading way and it is hoped that these inadequacies will be corrected in the next edition. Here are a few examples of what is meant: The discussion of the relative probabilities of neutron capture for fast and slow neutrons on page 109 is somewhat obscure, because no mention is made of the large de Broglie wavelength of thermal neutrons. On page 158 appears the statement: "Although the cross section for Rutherford scattering is about the same for alpha particles and electrons of the same energy, the probability that the alpha particle is scattered is much smaller because of its shorter range." Since cross section is presumably a measure of probability, this seems indeed a paradoxical statement. It is, in fact, quite wrong unless one compares the scattering of the electron over *its* range with that of the alpha particle over its (much shorter) range. On page 236, the authors touch briefly on the so-called isotope effect in chemical reactions, but confuse the issue thoroughly when they intimate that, in most cases, it is not important because "the compound which is to be traced is composed nearly entirely of stable material with just a minute admixture of the active element"—a statement that, while correct, has nothing to do with the case. No useful purpose would be served by quoting here the few additional passages which the reviewer has found objectionable—fortunately, they are very much the exception. But he should like to point out the improper use of the word



Exclusive combination monocular-binocular tube for photomicrography

Leitz® ORTHOLUX

the STAR among research microscopes



Another of the famous Leitz Microscopes . . . recognized everywhere as the finest microscopes made anywhere.

Now helping to chart new frontiers in all fields of scientific research, the Leitz ORTHOLUX is world-famous for outstanding precision and quality. To make the ORTHOLUX more useful than ever, Leitz now offers a combination monocular-binocular tube which enables you to photograph the microscope image without changing tubes. You change *instantly* from microscopic observation to photomicrography.

All the features needed for easier, less tiring observation:

- **Built-in illumination system for transmitted or incident light**
- **Berek double-diaphragm condenser**
- **Large, square built-in mechanical stage with *low set* drive**
- ***Low set* micrometer fine adjustment on *double ball bearings***
- **Counter-balanced coarse focusing**

for nuclear track work

Leitz MICRO-OPTICS

A new series of objectives and eyepieces designed especially for observation of cosmic ray "events" on nuclear tracks. Particularly recommended for use with the Leitz ORTHOLUX and Type "B" stand microscopes. Also may be used on other standard types of microscopes.

For further information write Dept. 104NU

E. LEITZ, Inc., 468 Fourth Ave., New York 16, N. Y.

LEITZ MICROSCOPES · SCIENTIFIC INSTRUMENTS · BINOCULARS

LEICA CAMERAS AND ACCESSORIES

introducing
C-3
methods manual

40 pages of Assembly Procedures

The C-3 Methods Manual is dedicated to the urgency of the good workmanship that must accompany the assembly of quality cables and connectors. Each advocated procedure has passed stringent screening, not only by Amphenol's engineers, but by other recognized experts in the electronic field.

The majority of Amphenol electronic components—and there are now over 9,000 in the standard line—were originally developed to fulfill a specific application problem. When you consult with Amphenol engineers in solving your electronic and power application needs, you will be working with one of the most specialized engineering staffs and testing laboratories in the electronic world.

To obtain your free copy of "OK Methods" mail this coupon to Department 13M.

AMERICAN PHENOLIC CORPORATION
1830 South 54th Avenue • Chicago 50, Illinois

NAME_____
COMPANY_____
ADDRESS_____ POSITION_____
CITY_____ ZONE_____ STATE_____

AMPHENOL

nuclide in the book; this word should be used to denote species of atom, not individual atoms.

The book is gratifyingly free of misprints. One of the few which caught the reviewer's eye and which could lead to much confusion is the mislabeling of the legend on Fig. 8.8 as mg/cm² instead of g/cm². The paper and printing are excellent and the book is attractively bound.

BOOKS RECEIVED

Annual Review of Nuclear Science—Vol. 2, 1953, J. G. Beckerley, ed., Annual Reviews, Inc., Stanford, Calif., 1953, ix + 429 pages, $6. (*To be reviewed.*)

Pharmacology and Toxicology of Uranium Compounds, Div. VI, Vol. 1, Parts III and IV, of National Nuclear Energy Series, edited by Carl Voegtlin and Harold C. Hodge, McGraw-Hill Book Company, Inc., New York, 1953, 1380 pages, $18. [Part I (The Pharmacology and Toxicology of Uranium Compounds) and Part II (The Pharmacology of Fluorine and Hydrogen Fluoride) of this NNES volume were published together in two books in 1949 ($14.25 per set); the present addition to this volume, Part III (Chronic Studies) and Part IV (Mechanism and Metabolic Studies), also appear in two books ($18 per set). No one part can be purchased separately.] (*To be reviewed.*)

Radioisotopes in Industry, edited by John R. Bradford, Reinhold Publishing Corporation, New York, 1953, vii + 309 pages, $8. Book based on series of lectures at Case Institute of Technology. (*To be reviewed.*)

The New Force, by Ralph E. Lapp, Harpers & Brothers Publishers, New York, 1953, x + 238 pages, $3.

This book is a good account for the layman of the development of nuclear-energy and its present and possible applications. The author recalls, sometimes with personal experiences, the developments in the past ten years and their significance for the future. Stewart Alsop has written the foreword.

Advanced Mathematics in Physics and Engineering, by Arthur Bronwell, McGraw-Hill Book Company, Inc., New York, 1953, xvi + 475 pages, $6.

This text, for students at the senior and graduate level, emphasizes the

underlying unity in the methods of mathematical analysis in the various fields of physics and engineering.

There are chapters on the infinite series; Fourier series and integral; ordinary differential equations; series methods of solving differential equations, including the Bessel, Legendre and associated equations; partial differentiation; Lagrange's equations; Hamilton's principle; vector analysis; functions of a complex variable; and Laplace transforms.

ALSO OF NOTE

Atomic Energy in Industry. Proceedings of a special conference held in New York and sponsored by the National Industrial Conference Board, Oct. 16–17, 1952; it contains the text of forty talks given by participants, together with transcripts of question and answer periods. *National Industrial Conference Board, 247 Park Avenue, New York, N. Y., $10.*

Thirteenth Semiannual Report of the Atomic Energy Commission (January, 1953). In its accounting to Congress of its activities from July–December, 1952, the AEC includes an annual financial report for fiscal year 1952 and a 49-page report on practices for public safety in its continental weapons tests. Ten appendices provide information on AEC organization, membership of committees, research, etc. The 210-page document can be ordered either under the title given above or its alternate title, **Assuring Public Safety in Continental Weapons Tests.** *GPO, Washington 25, D. C., $0.50.*

Fire Protection for Particle Accelerator Installations. A 61-page booklet prepared by the Joint Fire & Marine Insurance Committee on Radiation. *W. Forristall, Chairman, 555 Asylum St., Hartford 2, Conn., $1.*

Proceedings of the Conference on "Building in the Atomic Age." A 115-page illustrated record of the conference sponsored by and held at MIT in June, 1952, for the purpose of discussing the general effects of atomic bombs, design of above-ground and below-ground structures, government programs, and economics of structures in the atomic age. Fifteen papers, with discussion, are included. *Dept. of Civil and Sanitary Engineering, Massachusetts Institute of Technology, Cambridge, Mass., $3.*

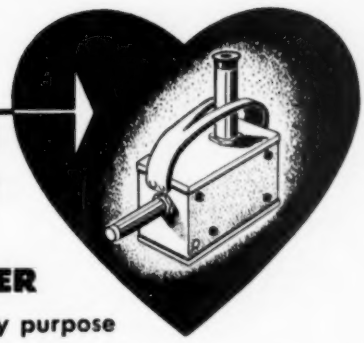
at the heart of...

radiation measurement and still growing in versatility

THE VICTOREEN

CONDENSER r-METER

...with a chamber for every purpose



For years the Victoreen Condenser r-meter has fulfilled its designed function as a secondary standard of radiation measurement. The r-meter continues to grow in versatility and reliability—while retaining its world-recognized accuracy and its simplicity of operation. The Condenser r-meter is a compact, portable, battery-operated instrument for the precise measurement of gamma radiation and X-ray dosage in International Roentgens. Detachable ionization chambers are charged in the r-meter, placed in the radiation field, then returned to the r-meter where total exposure in Roentgens may be read.

VERSATILE...IN CHAMBER SELECTION

TYPE	RADIATION SPECTRUM KeV (EFFECTIVE)	CHAMBER MODEL	RANGE (r)	OUR CALIBRATION STANDARD IS
Hi-Energy X-Ray CO^{60} Ra	2000 to 400 KeV.	552 553 554	0-2.5 0-25 0-250	A secondary-standard chamber calibrated at the Bureau of Standards on CO^{60} and Ra*. *There is no primary standard for the Roentgen above 400 KeV.
Medium Energy	400 to 50 KeV.	130 70-5 131 154	0-.25 0-25 0-100 0-250	Primary standard air chamber over the range 180 to 25 KV.
Low Energy	50 to 20 KeV.	365	0-250	Primary standard air chamber over the range 180 to 25 KV.
Gamma Ray	I 131	503	Curie	Simulated I 131 source.
Beta measuring	10mg/cm² wall	576 577 578	0-.25 0-2.5 0-25	Not calibrated. Wall equivalent to epidermis layer of human skin.

VERSATILE...IN APPLICATION

Check This Partial List

THERAPY AND DIAGNOSIS
Dose Control
Phantom Measurements
Gamma Isotope Measurements

CALIBRATION
Of Secondary Standards
Of X-ray Equipment
For Military Specifications

HEALTH PROTECTION MEASUREMENTS
X-ray Machine Shielding
Isotope Shipments
TV Projection Tubes
X-ray Shoe Fitting

STUDY OF BIOLOGICAL EFFECTS FROM TOTAL DOSE

STUDY OF ORGANIC EFFECTS
Food Preservation
Sterilization
Bacteriology
Genetics
Agriculture

STUDY OF INORGANIC EFFECTS
Electrical Properties of Insulators
Structure and Composition of Glass and Metals

PRODUCTION CONTROL
X-ray Machines
X-ray Tubes

DIRECT MEASUREMENTS
Electrostatic Voltmeter
Electrostatic Capacity Checker
Hi-Meg Resistor Checker

Pride in accuracy of calibration using the most complete commercial X-ray calibration facilities in the world has long been the keynote in Victoreen's contribution to radiation measurement.

BETTER COMPONENTS MAKE BETTER INSTRUMENTS

The Victoreen Instrument Co.

5806 HOUGH AVENUE, CLEVELAND 3, OHIO

Want more information? Use post card on last page.

OPTICAL SYSTEMS

INDUSTRIAL PERISCOPES

DESIGN
DEVELOPMENT
MANUFACTURE

For nearly half a century Kollmorgen has designed, developed and manufactured precision optics and optical systems for industry and the military.

We have the engineering "know-how", the design personnel and the manufacturing capacity to help you solve your optical problem.

KOLLMORGEN Optical CORPORATION

Plant: 347 King Street • Northampton, Mass.
New York Office
30 Church Street
New York 7, N. Y.

LETTERS

A Way to Interest Industry

DEAR SIR:

I would like to compliment NUCLEONICS on its strong policy of publishing articles of information concerning the AEC's reactor program, and particularly the study results and feelings of the various industrial and utility groups who are participating in the power-reactor feasibility studies.

It is generally realized that with the help of a revised version of the Atomic Energy Act of 1946, industry can be permitted to participate in the atomic energy business independently. It was clearly pointed out in your report on *World Progress in Atomic Energy* (NU, Dec. '52, pp. 7-35) that industry in other countries is vitally interested in participating (and in a couple of countries industry is already actively engaged with their own funds). This emphasizes the need of our own concerns' taking active interest in this new field. Existing impediments should be eased, if not lifted, for them. The Detroit Edison-Dow Chemical Company combined decision to allot some of their own private funds to build a nuclear-powered reactor principally for electric generation purposes is a large instigating factor for Congress to act on modernizing the present Atomic Energy (McMahon) Act of 1946. Until the Act is amended, the Edison-Dow reactor cannot be started. Here is an urgent need for such action, and, no doubt, more will follow suit when the restrictions are relaxed.

When some of the classification veils have been eliminated, I believe that there exist a few groups who, if authorized to do so, could assist the AEC in introducing interested industrial concerns to the potentials existing for them in the atomic energy business. One of these groups, in particular, is the Nucleonic Committee of the American Institute of Electrical Engineers (AIEE). This committee, composed of AIEE electrical engineers, scientists, physicists, and administrators, is attempting to keep pace with the electrical advancements made in the broad nucleonics field and to report the progress to the AIEE and its members. They would be in a logical position to assist the utilities, for example, in becoming interested in power-producing reactors. Possibly the Edison Electric Institute could initiate a similar group of industry members for the same purpose.

The industrial research organizations, such as the Stanford Research Institute, Armour Research Foundation, Southern Research Institute, Midwest Research Institute, and the like, could assist industry's research organizations and the educational institutions in a similar manner on research activities. These are only a few of the potential groups which could be brought into action (if they are willing) to spread interest in atomic energy activity. Your NUCLEONICS staff of qualified experts could also do a similar job. We have qualified groups to form the drive.

I would like to point out here the splendid work which Mr. W. L. Davidson and his Office of Industrial Development of the AEC are performing for the AEC and industry. What with the secrecy cloaks presently required on atomic energy data, Mr. Davidson and his small group are effectively helping far-sighted industries and individuals in their search for atomic energy information and chances of participation. Just imagine what they could do when some restrictions are lifted.

Compliments are also in order on your stand for the necessity of some immediate relaxation to the Atomic Energy Act of 1946. I am sure it has aided many NUCLEONICS readers in formulating similar opinions of their own. Keep up the good work in your editorials, published articles, and news events on this subject. Industry needs it as vital information.

A. DONALD TAYLOR
Atomic Power Division
Westinghouse Electric Corporation
Pittsburgh, Pennsylvania

(In regard to Mr. Taylor's statement of Edison-Dow's decision to allot their own funds for a power reactor, it is NUCLEONICS' understanding that this decision is not final but rather awaits the completion of feasibility studies still in progress.—Editor)

Thermonucleonics in Argentina

DEAR SIR:

As a reader of NUCLEONICS, I always am anxious to get the next issue in order to learn what interesting themes are published.

But reading the December issue [NU, Dec. '52, p. 30], I have been a little puzzled by your lithium story which concerns my work in atomic energy development.

Please do me the favor and read the article which I published in the July, 1951, issue of the *United Nations World* and you will find a much better lithium story in it.

In the same NUCLEONICS issue [p. 82] you report about peacetime applications of hydrogen-bomb reactions—well, you should ask Dr. Harold C. Urey about it and he undoubtedly will tell you the truth about the new kind of chain reactions which would have made your lithium story a little more interesting.

I tell you all this because I am a subscriber of NUCLEONICS for many years and I would like to keep this interesting paper free from intolerance.

With my best wishes for NUCLEONICS and warmest regards, I am

RONALD RICHTER
San Carlos de Bariloche
Argentina

(*In the* United Nations World *article, Dr. Richter spoke of Argentina's atomic energy pilot plant on Huemul Island, where he claims he and his associates are using lithium-6 to produce "the new type of neutron chain reaction so decisive in thermonuclear bombs." It was at Huemul on February 16, 1951, he noted, that "we . . . successfully tested our thermonuclear reactor." He added, also, that "we have a large scale thermonuclear reactor under construction and it should be possible to have this 'atomic furnace' in full scale operation in about ten months or so." In view of the fact that it is twenty months since these statements appeared, the editors have invited Dr. Richter to use the pages of* NUCLEONICS *to bring our readers up to date on his experiments with lithium and to describe his thermonuclear reactor in such detail as to erase any misunderstanding of the work that the world may have.*—Editor)

as the leading manufacturer of scintillation counting equipment...

NUCLEAR RESEARCH CORP.
is proud to introduce
the SC-2A
Scintillation Counter

Utilization of the new RCA 6199 multiplier phototube together with the best possible optical coupling between crystal and tube has made possible an extremely small (2" dia. x 7" long) instrument which combined with a large (1" x 1") NaI (Tl) crystal has extremely high efficiency for gamma detection.

A long plateau, excellent reproducibility of results, and a 6' cable conveniently connecting to the G-M input of any conventional scaler or ratemeter make this the ideal instrument for a wide variety of gamma counting problems.

Price $240.00 complete
Write for Bulletin SC-203, Supplement I

nuclear research corp.
2563 Grays Ferry Avenue • Philadelphia 46, Pa.

NUCLEONIC EVENTS

U. S. Lends Canada Technical Aid on Damaged Reactor; Will Ship Isotopes Until Reactor Is Back in Operation

With the U. S. under severe criticism for not exchanging information on nuclear energy with foreign nations, Atomic Energy Commission chairman Gordon Dean was pleased to be able to offer U. S. technical aid and assistance to Canada following the December accident at the NRX reactor at Chalk River. Dean, in an interview with NUCLEONICS, said that as soon as word of the accident was received, he offered full cooperation to the Canadians, including sending a team of AEC experts to the scene and shipping radioisotopes.

Despite present difficulties in international exchange of atomic energy information, this cooperation was made possible because "Canada has no law restricting its dealings with the U. S. on atomic matters," Dean said. This is left up to administrative authorities. Dean pointed out that this exchange of aid and information would be much more difficult if the accident had occurred at a classified AEC reactor.

This is a "fair example" of the limiting factors of the present law as it pertains to cooperation with other countries, Dean said. It also "offers a good example of the folly it would be if we couldn't take full advantage of such opportunities." Dean implied that we cannot rightfully expect other countries to share information with us unless we have legal authority to share ours with them.

Sensitivity of the information to be gained from the Chalk River accident "is not great," Dean said. But if the U. S. extended the same cooperation to the Canadians, "we would be measuring the language of the law right up to the limit."

The accident was the result of an unusual series of coincidences. The reactor had been shut down, and the flow of cooling water was considerably lower than that for full operation. Because of a misunderstanding, all the control rods were suddenly pulled out, and the power in the reactor built up very rapidly.

This rapid build-up of power, combined with the small flow of water, caused at least one of the fuel rods to vaporize, and many thousands of curies of radioactive gases were carried up the exhaust stack. Because of unusual atmospheric conditions, these gases were not widely dispersed.

According to Dean, AEC scientists had previously speculated on the effects of such an accident. There had even been several suggestions that experiments along these lines might be profitable. However, because of the cost involved, both in time and materials, no serious thought was given to the idea.

Thus AEC was glad to be able, at the invitation of the Canadians, to dispatch a team of 17 scientists and technicians to study the nature and effects of the accident. The group included two or three of the commission's top reactor experts.

Information gained in the fields of safety control, preventive measures, radiation effects, and actual physical damage to the Chalk River plant, would be of "substantial value" in adding to the knowledge of reactor technology and the prevention of reactor malfunction.

During three days spent at the site, the U. S. group also ascertained the types of assistance that would be useful. Upon return of this group, AEC sent six experts, including AEC and Navy personnel, to aid in decontamination operations. Arrangements have also been made for loan and, in some cases, sale of U. S. equipment for these operations and for repair of the reactor.

Until NRX is back in operation, AEC is undertaking to ship U. S.-produced radioisotopes in bulk quantities to Chalk River to help the Canadians meet their commitments. Additional assistance will be offered, within the limits of present law and agreements, should the Canadians need it.

Dean Resigns as AEC Chairman, Continues as Member; Chairmanship of Congressional Committee in Dispute

Gordon Dean, who has been chairman of the Atomic Energy Commission since July, 1950, has submitted his resignation as chairman but will remain as a commissioner, probably until his term expires in June, 1953. Dean's intention to resign was first reported in NUCLEONICS (Dec. 1952, p. 82).

It was pointed out in December that the man appointed by President Eisenhower to fill the vacancy left by the resignation of T. Keith Glennan would probably succeed Dean as chairman. This would assure that the terms of the present and future chairmen will overlap and that responsibility would be transferred in an orderly manner.

Indecision still exists as to who shall be chairman of the Joint Congressional Committee on Atomic Energy. The two candidates are Senator Bourke B. Hickenlooper, R., Iowa, and Representative W. Sterling Cole, R., N. Y.

The Representatives feel that since the chairmanship was last held by a Senator (the late Brien McMahon), a member of the House should now be chairman. The Senators contend that the chairman should be a member of the Senate since that body alone has the Constitutional duty of approving appointments to AEC and of ratifying any treaties with foreign nations, including treaties on atomic energy.

Partisan politics is not involved in the dispute. The Joint Committee is composed of 9 Representatives and 9 Senators. In the present Congress, 5 of each are Republicans, and 4 are Democrats.

Two new members of the committee are Sen. Guy Cordon, R., Oregon, and Rep. Thomas Jenkins, R., Ohio.

Lilienthal Recommends McMahon Act Revision

Revision of the Atomic Energy Act of 1946 to enable private industry to enter the atomic energy field on a competitive basis and to eliminate all but weapons secrecy has been recommended by David Lilienthal, who was chairman of the Atomic Energy Commission from October, 1946, to February, 1950.

In an interview with the *St. Louis Post-Dispatch*, he suggested that the President create a citizen's commission that would make recommendations for a new atomic energy law. He feels that there are three important reasons why the law should be changed:

First, there is no longer any basis for existing policy, and the secrecy demanded by that policy is more fiction than fact.

Second, if private enterprise could develop the atomic energy field, great benefits to mankind would result.

Third, there are serious dangers in continued governmental domination of ideas and technical thinking in this field.

These recommendations do not imply relaxation of secrecy in the military aspects of atomic energy, but Lilienthal feels that the security blanket covers too much. This is particularly true, he says, in the case of things that are known by others and that we still label secret.

For membership on the proposed commission, Lilienthal suggests young men without AEC or Congressional experience in the field. He feels that they should not be bound by the limitations of habits of thought in connection with the problem.

"We have a great atomic industry that has sprung up in a decade," he says. "It represents no private investment, no risk of loss nor chance of profit.

"But even worse than this unusual condition is the amazing situation that in this whole new field the question of who shall think about problems, how much effort shall be expended in certain directions, what ideas may be pursued, is all a matter for the Government to decide."

The specific recommendations he made are:

1. Closer control on the weapons side. This would apply only to what is still really secret, and not to information labeled secret but known to others.

2. Removal of Government monopoly of ideas in the area of manufacture of atomic materials.

3. Opening up of the field of power reactors.

4. Private ownership of fissionable materials, under appropriate licensing and with the owners fully accountable.

5. Eventual private ownership of the AEC plants at Oak Ridge, Tenn., and Hanford, Wash. An interim step in this denationalization would be to have the Government operate the plants through cost-plus contractors.

The new law should start by admitting that the secrecy policy has not given what was expected of it. This would mean that information about such processes as those at Oak Ridge and Hanford that do not have military importance could be made available to private industry.

Lilienthal thinks that this might release a great flow of industrial and chemical possibilities that have nothing to do with weapons, or even with atomic energy as such.

Weapons Tests Result in Little Long-Term Activity

Studies of the long-term effects of the fall-out of radioactivity from the weapons tests at the Nevada proving ground indicate that the residual activity is less than normal background. By January 1, 1953, the radioactivity resulting from the spring 1952 test series had decayed to levels that had no significance as sources of external radiation.

The results of these studies, in which measurements of residual activity were made throughout the country, have been made public in the 13th semi-annual report of the Atomic Energy Commission.

Total radioactivity remaining on January 1, 1953, in communities inside a 200-mile zone around the proving grounds, as a result of the eight detonations in the spring 1952 series, was measured in samples collected over a 24-hr period. The activities varied from 740 dpm/ft^2 at one locality to 117,000 dpm/ft^2 at another. These are beta counts, but the highest of them represents gamma exposures estimated to be less than that resulting from normal background radiation.

Similar measurements throughout the country showed residual activities varying from 100 to 14,000 dpm/ft^2, depending on location.

The radioactivity remaining in the soil in Nevada and surrounding states as a result of the series of tests held in the spring and fall of 1951 and the spring of 1952 is also low. After the first test series, the activity died off. The second test raised the level, which then died off until the third test again raised the level. The peak of activity, just after the third test, was less than half the natural activity in the top 12 in. of the earth's crust.

Facilities to Be Built for Aircraft Reactor Tests

Ground testing facilities for a prototype aircraft propulsion reactor will be constructed at the National Reactor Testing Station, Arco, Idaho. The Air Force and General Electric Co. have established offices for the aircraft nuclear propulsion project in the Atomic Energy Commission's administration building, Idaho Falls, Idaho.

The proposed facilities include an assembly and maintenance area and an administration area. Cost of construction is expected to exceed $6-million. Bids for the construction were received last month.

Eventually, $33-million will be spent on ground test facilities for prototype nuclear aircraft power plants.

Development of a power plant and propulsion units for nuclear powered aircraft is being done at General Electric's aircraft gas turbine division, Lockland, Ohio.

Design Studies Underway for Multi-Bev Synchrotrons

Design studies for three multi-Bev strong-focusing synchrotrons are underway with funds supplied by the Atomic Energy Commission. The strong-focusing principle, which makes multi-Bev machines economically feasible, is a new development by three Brookhaven National Laboratory scientists (NU, Nov., '52, p. 106; Jan., '53, p. 12).

A total of $250,000 has been made available for the three studies. Brookhaven has received $100,000, and Princeton and a combined group from Harvard and Massachusetts Institute

For Measuring RADIOACTIVE EMISSIONS

8.3 x 6.3 x 3. 5 cm. Weight 0.17 kg.

LINDEMANN-RYERSON ELECTROMETER

Was first used for photo-electric measurements. Is now used in conjunction with ionization chambers for the determination of radioactive emission. Compact, sturdy, high sensitivity, stable zero and requires no leveling. Capacitance is about 3 cm. Includes improvements developed by the Ryerson Laboratory.

PORTABLE Projection Viewer for Lindemann-Ryerson Electrometer.

GAMMA RAY POCKET DOSIMETER

is a personnel monitoring instrument to measure cumulative exposure to gamma or x-rays over a given period. Contains an ionization chamber, a quartz fiber electrometer and viewing system.

"CHANG and ENG" FAST NEUTRON DETECTOR

follows closely original design of U. S. Atomic Energy Commission. Consists of twin ionization chambers, Lindemann Electrometer, reading microscope and dry cells. Self contained.

PRECISION IONIZATION METER (Failla Design)

A complete instrument for null methods of radioactivity measurements where background radiation effects must be eliminated.

Send for complete information

CAMBRIDGE INSTRUMENT CO., INC.
Pioneer Manufacturers of Precision Instruments
3774 Grand Central Terminal, New York 17

of Technology have each received $75,000.

The Brookhaven group, headed by Leland Haworth, is considering machines of 30 Bev, and up. The MIT-Harvard group, headed by M. Stanley Livingston, and the Princeton group, headed by Milton G. White, are considering machines in from 10 to 15 Bev.

The groups are working independently, each trying to find the most suitable design for its purposes. When the studies are complete, which is expected to be in a few months, AEC will decide which, if any, to support, or whether to support two or three.

Accelerators, Fission Products Vie for Sterilization Use; Application Delayed by Feeding Studies, Basic Research

Use of radiation sterilization in food and pharmaceutical processing will be delayed by feeding and clinical testing programs and by side-effect studies. Meanwhile, Van de Graaff and other electrostatic generators are being used for a large portion of the research, and offer real competition to fission products for final use in this field. This was indicated at a symposium on "Action of Ionizing Radiation on Biological Systems" at the Polytechnic Institute of Brooklyn on Feb. 7.

Electron generators have a technical advantage in that radiation energy and dose rate are more easily varied. Economic comparison is vague, however.

Representatives of General Electric Co., High Voltage Engineering Corp., and Electronized Chemicals Corp. all agree that a "few tenths of a cent per pound" of food would cover all generator sterilization costs, including amortization of equipment over a period of 5 to 10 years. These estimates are based on actual research experience.

In contrast, no actual cost data are available for fission products. Estimates made in the Stanford Research Institute fission-product study (NU, Jan., '52, p. 45) were based on assumed market conditions. And the future fission-product market is so uncertain that, according to S. A. Lough of AEC's Isotopes Division, "industry won't invest in [the necessary] fission-product refining plants at this time."

Much of this uncertainty is caused by the necessity of winning acceptance and approval of radiation processing by government regulatory agencies and consumers. To get this acceptance, absence of deleterious effects will have to be proved by animal feeding of irradiated foods for perhaps two years, and by large-scale clinical testing of irradiated pharmaceuticals.

Limited studies are already underway. Feeding programs at the University of Michigan and Columbia University are restricted by available radiation sources, but will be extended in the future. The Upjohn Co. has used about 2,000 clinical doses of Van de Graaff irradiated antibiotics and vitamins. Schering Corp. has accumulated five years of toxicity and stability information on irradiated pharmaceuticals, but on a laboratory scale.

Other factors complicate the outlook for the future. All speakers at the symposium agreed that the dose required for sterilization varies with the product to be sterilized and with the organisms to be killed. Apparently dose rate has some effect, for radioresistant organisms have been produced at low dose rates.

Once a sterilization dose is determined for a particular application, accurate dosimetry will be required to assure that that dose is administered. Many forms of physical and chemical measurement are being used in present research, and the difficulty that exists in correlating experimental results indicates that some standardization of dosimetry will be required for wide-scale routine uses. AEC is expected to take the lead in this.

Another factor receiving considerable attention is radiation side effects such as flavor changes in foods. Means of eliminating some side effects have been found, and the basic mechanisms of radiation ionization in biological systems are being studied intensively at MIT, Columbia, Yale, Michigan, and other laboratories.

In spite of the need for added research, at least limited application of radiation sterilization seems certain. A year ago, at a similar conference, crystal-ballers foresaw replacement of other sterilization methods. Now, it is recognized that radiation will supple-

ment, not supplant, other methods.

And the potential market appears to be large. A Department of Agriculture representative at the symposium pointed out that food spoilage amounting to over $30-million annually might be eliminated by irradiation of citrus fruits, apples, potatoes, and grains to control molds, rot, and insects. S. L. Galvin, of Pepsi Cola Corp., suggested use of radiation to extend time of freshness of vegetables and to sterilize spices. L. E. Brownell of Michigan reported preliminary studies of trichinosis control, but this method is opposed by representatives of meat packers, who claim that cooking of garbage is an adequate control.

British Plan to Build Large Dual-Purpose Reactor

The British Ministry of Supply, which is responsible for atomic energy matters in that country, is looking for a site on which to build a dual-purpose reactor, according to Duncan Sandys, Minister of Supply. It is planned that the electric generation part of the plant will be of considerable size.

A small experimental reactor of this kind, to generate power and breed plutonium, is under construction at Harwell, and is expected to be completed sometime this spring. Construction of the larger reactor will await experience with this one.

Sandys said that no plans are being made to undertake work on propulsion reactors "until more experience has been gained in the development of stationary nuclear power plants."

Radiation Research Society Plans Annual Meeting

The annual meeting of the Radiation Research Society will be held June 22–24, 1953, at the State University of Iowa, Iowa City. The program will consist of two symposia, invited talks, and contributions of original research.

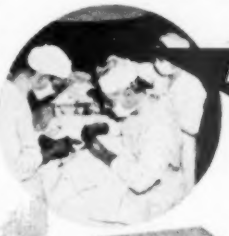
The first symposium is entitled *The Effects of Radiation on Aqueous Solutions* and includes the following speakers, E. S. G. Barron, Edwin J. Hart, Warren Garrison, J. L. Magee, and A. O. Allen. The title and speakers for the second symposium are *Physical Measurements for Radiobiology*, Ugo Fano, Burton J. Moyer, G. Failla, L. D. Marinelli, and Payne S. Harris.

The two invited talks are on meson

IN THOSE EXTRAORDINARY APPLICATIONS WHERE DEPENDABILITY AND PRECISION COUNT

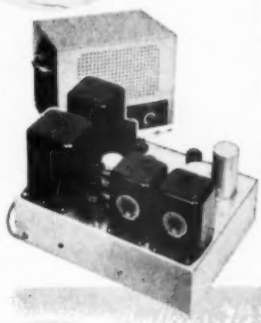
you'll find **CHICAGO**

the World's Toughest Transformers



A "LOCATOR" FOR SURGERY

The Kirby-Thurstone Cholelithophone is an ingenious electro-acoustic device for the detection and location of gallstones in the common and hepatic ducts. This fine aid to surgery is a joint development of the University of Pennsylvania Hospital and Pennsylvania State College. The precise and dependable instrument is manufactured by Centre Electronic & Mfg. Co. CHICAGO Sealed-in-Steel transformers are specified and used exclusively for the completely dependable performance required of the instrument.



C-TYPE Sealed-in-Steel, with leads and flange mount

SAFETY FOR A SUPERLINER

Photo Courtesy Newport News Shipbldg. & Dry Dock Co.

The *S. S. United States*—last word in Superliners—incorporates every known seagoing safety device. Among its electronic safety features is the Announcing System Amplifier, designed and built by Electronic Engineering Company, Inc., of Norfolk, Va. The power transformer specified and used in this super-dependable amplifier is by CHICAGO. Where dependability is an absolute requirement, you'll find CHICAGO—the world's toughest transformers.

S-TYPE Sealed-in-Steel, with lug terminals and flange mount

Free "New Equipment" Catalog

You'll want the full details on CHICAGO'S *New Equipment Line*, covering the complete range of "Sealed-in-Steel" transformers for every modern circuit application. Write for your Free copy of Catalog CT-153 today, or get it from your electronic parts distributor.

CHICAGO TRANSFORMER

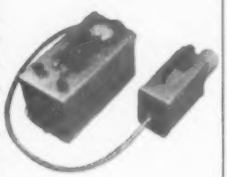
DIVISION OF ESSEX WIRE CORPORATION

3501 ADDISON STREET, CHICAGO 18, ILL.

Export Sales Div.: Scheel International, Inc. 4237 N. Lincoln Ave. Chicago, Ill., U.S.A. CABLE ADDRESS: HARSHEEL

Neutron Dosimetry

A variety of Raychronix instrumentation for fast neutron studies is now available. For instance, if your problem requires precise dose measurement, the E-3 Pulse Integration System (above) may be the answer. Or, the E-1 Fast Neutron Dosimeter (below) may better fit your needs.



Gamma-discriminating counters, tissue equivalent chambers and similar detectors can now also be supplied. Borated paraffin fast neutron source containers, too, are available.

Why not let us discuss your requirements with you? Complete catalog on request.

Radioactive Products, Inc.

RAYCHRONIX

443 W. Congress Detroit 26, Mich.

physics, by L. W. Alvarez, and on an unannounced subject, by L. H. Gray of the Hammersmith Hospital, London. Dr. Gray's lecture is sponsored by the Iowa Branch of the American Cancer Society.

Anyone desiring to report original research in radiation effects, or interested in attending, or desiring additional information should contact the secretary of the society, A. Edelman, Biology Department, Brookhaven National Laboratory, Upton, N. Y.

New AEC Weapons Plant to Be Built in Illinois

A new plant for processing and assembly of explosives will be built by the Atomic Energy Commission on a site 18 miles east of Macomb, Illinois, on the Spoon River in Fulton County. The new plant will not manufacture radioactive material.

Construction of the new plant, to be named the Spoon River Plant, and estimated to cost about $29-million, will begin in the early spring and is expected to be finished in 1954. An engineering office to supervise construction will be established. W. A. Curtis, chief of the production planning branch, Santa Fe Operations Office, is the project engineer in charge of construction of AEC. Fluor Corp., Los Angeles, Calif., is architect-engineer for the project.

The plant will be operated by a private contractor not yet selected. Employment of operating personnel will not exceed 2,000; hiring will not begin until construction is nearly complete.

RAW MATERIALS

• **Tennessee.** A new phase has been initiated in AEC's long-range program of studying uraniferous shales of the southeastern U. S. The Bureau of Mines will soon start operation of a small experimental mine near Sligo, Tenn., to develop satisfactory methods of mining the shales.

Minute quantities of uranium are contained in these shales, and they are of long-range interest as a potential domestic uranium reserve. A widespread drilling program is being conducted by the Geological Survey to obtain better knowledge of the uranium occurrences.

• **New York.** Columbia University has entered into a $550,000 contract with AEC to do development work on recovery of uranium from the bituminous shales of southeastern U. S. The amount of uranium in these shales is very small, but AEC is attempting to develop effective processes for extracting uranium from all known domestic sources.

CLARK E. CENTER has succeeded George T. Felbeck as vice-president in charge of atomic energy work of Carbide and Carbon Chemicals Co. His responsibilities include production of U-235 at Oak Ridge and eventually at Paducah; isotope production at Oak Ridge; and research, design, and construction of reactors contributing to propulsion and stationary-power units. He has been in atomic energy work with the company since 1943, when he undertook to coordinate the construction and staffing of the K-25 gaseous-diffusion plant

• **Norway.** Geologists are surveying graphite deposits in Glomfjord, North Norway, that have been shown by preliminary tests to contain 100–200 grams of uranium per ton.

• **India.** A factory to process uranium ore and produce uranium and thorium compounds is to be set up in the southern part of Bihar State, where deposits of these two minerals are known to exist.

IN BRIEF

• **Reactor waste.** It is reported that there are 10 megacuries of radioactive waste stored at AEC's Hanford production center.

• **Commercial reactors.** The Cincinnati plant of Bendix Aviation Corp. has been designated the company's production group in atomic energy. If Bendix builds nuclear reactors, they will be built in Cincinnati. At the company's Detroit research center, 35

scientists are studying both commercial-power and military reactors, and the fruits of the research are destined for the production programs at Cincinnati.

• **Savannah security.** AEC's Savannah River plant, now in construction, has been closed to the public. Access is restricted to persons employed at the plant and to others authorized to enter on official business.

• **Computing center.** New York University has become the operating contractor for a computing center to serve the needs of AEC installations and contractors in the northeastern area. The center's first computing machine is the UNIVAC #4, built for AEC by the Eckert-Mauchly Division of Remington Rand.

NUCLEAR NEWSMAKERS

Ellison Taylor has been appointed assistant research director for chemistry and metallurgy at Oak Ridge National Laboratory. Also at the laboratory, **John Swartout** has been appointed deputy director of research in addition to his duties as director of the homogeneous reactor project.

Wilbur E. Kelley has resigned as manager of AEC's New York Operations Office to accept a position as vice president in charge of engineering with Catalytic Construction Co. His successor is **Henry B. Fry,** who has been deputy manager of NYO since July, 1950.

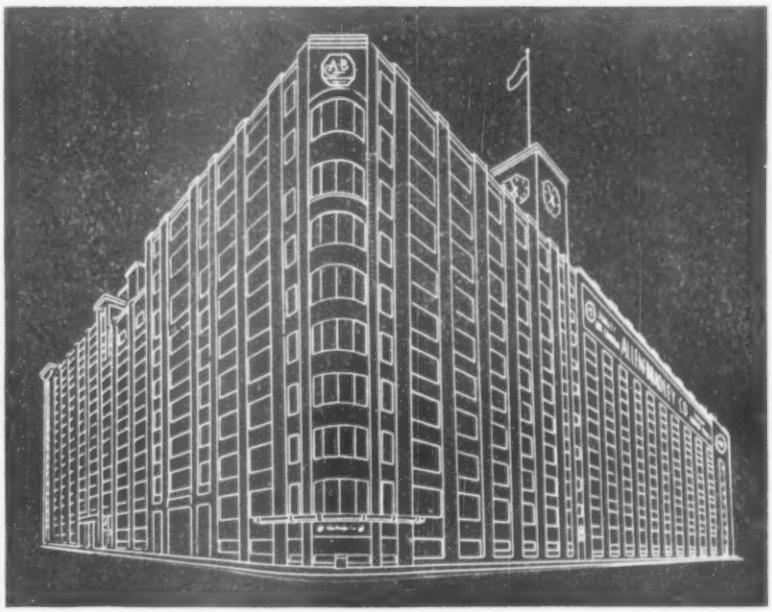
J. J. Barker has been appointed head of the process department of Walter Kidde Nuclear Laboratories. He formerly worked on the design of process equipment for the K-25 gaseous diffusion plant at Oak Ridge.

George A. Kolstad has been appointed chief of the physics and mathematics branch of the AEC's division of research.

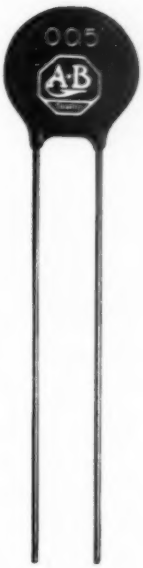
Arthur F. Erwin and **Edward F. Brill** are now manager and chief engineer, respectively, of Allis-Chalmers atomic power section. The section develops and manufactures reactor structures and components.

James E. Reeves is the new director of the office of test operations of the Santa Fe Operations Office. He will be responsible for coordination of programs at AEC's two weapons proving grounds.

ALLEN-BRADLEY



. . . A DEPENDABLE SOURCE OF HIGH QUALITY CERAMIC CAPACITORS



• If you use ceramic capacitors, you will be interested in Allen-Bradley as a source, because we make the entire capacitor from dielectric discs to the finished and tested units.

Allen-Bradley ceramic discs of high K dielectric material are molded by precision methods. After the discs are sintered, silver paste is applied to each side and heat treated. After the leads are soldered to the silver surfaces, the capacitor is insulated and wax impregnated. All manufacturing processes are Allen-Bradley controlled.

Allen-Bradley ceramic capacitors are available from 0.00047 to 0.01 microfarads. They are approved by the engineering departments of the leading electronic, electrical, and telephone laboratories.

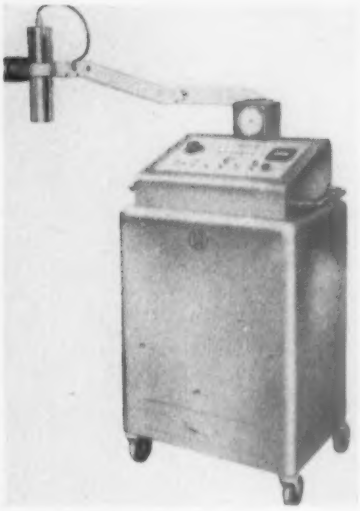
Allen-Bradley . . . long famed for high quality electronic components . . . is at your service as a major supplier of ceramic capacitors of superlative quality. Send for samples for your qualification tests.

Allen-Bradley Co., 106 W. Greenfield Ave., Milwaukee 4, Wis.

ALLEN-BRADLEY
RADIO & TELEVISION COMPONENTS
QUALITY

Want more information? Use post card on last page.

PRODUCTS AND MATERIALS



Medical Scintillation Detector

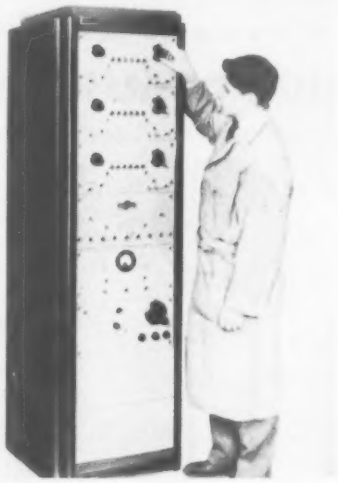
Nuclear Research and Development, Inc., 1094 Sutter Ave., St. Louis 5, Mo. The model C-2000 scintillation detection unit, for medical use, employs a NaI(Tl) crystal and a shielded RCA 5819 photomultiplier tube mounted on a balanced, flexible arm. The scaler portion of the unit incorporates a linear amplifier with gain of 0–1,200, pulse-height discriminator with 0–100 volt discrimination, a power supply regulated to 0.005% change in output for 1-volt change in input, and a scale of 128. The unit is mounted on a portable cart. (P-1)

Servo Tester

Industrial Control Co., Wyandanch, Long Island, N. Y. The 101-A servo tester shows the transient response of the loop under test on a 3-in. cathode-ray screen. The operator adjusts the servo loop until the test response matches the required response drawn on a mask. A servo-test receptable, installed on the unit to be checked, is connected to the tester by a single plug-in cable. (P-2)

Plastic Pipe

Elmer E. Mills Corp., 2930 N. Ashland Ave., Chicago 13, Ill. The Mills III transparent plastic pipe and fittings of cellulose acetate butyrate are available in sizes from ½ in. through 4 in. The plastic is said to be highly resistant to chemical attack and is suitable for handling oils, gases, water, and many chemicals. Sections are joined by a solvent cement, requiring no threads; they may be cut apart with a hand saw. Pipes are flexible, permitting wide-radius bends. Sizes up to 2 in. have a working pressure of 100 lb/in.^{2} at 100° F. (P-3)



Pulse-Integration System

Radioactive Products, Inc., 443 W. Congress St., Detroit 26, Mich. The model E-3 pulse-integration system, designed for fast-neutron radiation studies, is custom-made to individual requirements. A multichannel discriminator injects pulses into a scaling system in a manner that weights them according to amplitude. Auxiliary equipment can be supplied, including nondirectional counters to approximate a tissue-equivalent cavity and a precision pulser for checking operation of the system. Provisions can be made for local or remote operation and for automatic preset-time counting. (P-4)

Neutron Counter

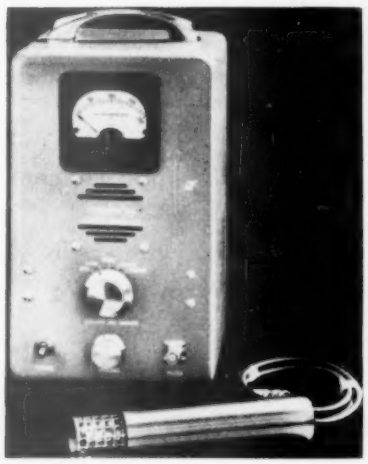
Radiation Counter Laboratories, Inc., 5122 W. Grove St., Skokie, Ill. The enriched BF_3 neutron counter is of all-aluminum construction. The end sections are aluminum-welded, and the counter is helium leak-tested before filling. Counters are available with filling pressures of 12 and 150 cm Hg. The diameter is 1 in. with active lengths of 6, 12, and 20 in. (P-5)

High-Speed Trigger

Walkirt Co., 145 W. Hazel St., Inglewood, Calif. The type M1563 high-speed trigger is a Schmitt-type circuit designed to supply 0–1.0-Mc pulses to drive counting or scaling equipment

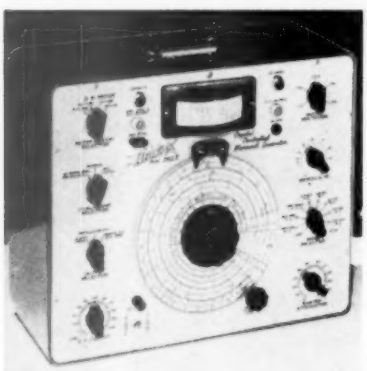
Want more information? Use post card on last page.

from a sine-wave input. Acting as an amplifier, the unit also produces pulses of positive or negative polarity from a square-wave input. The 150-volt peak-to-peak output has a rise time of 0.2 μsec and a fall time of 0.45 μsec, measured to 90% amplitude. The plug-in unit has an 11-prong octal-style base. (P-6)



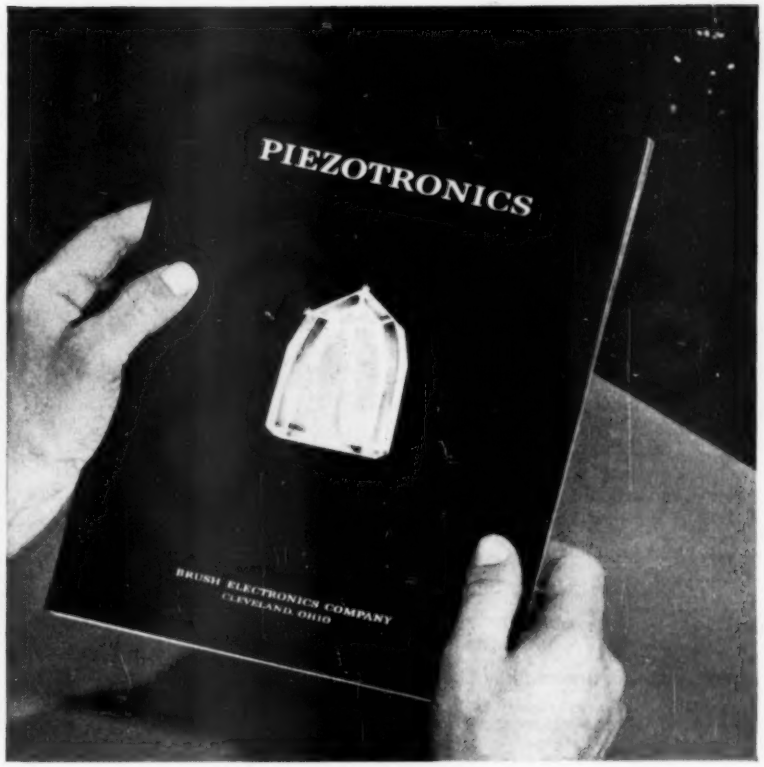
Laboratory Monitor

Beckman Instruments, Inc., Berkeley Scientific Division, 2200 Wright Ave., Richmond, Calif. The model 1800 laboratory monitor is a general-purpose counting-rate meter with visual and aural indication. Range selection is 300, 1,000, 3,000, 10,000 and 30,000 cpm with an accuracy of ±5%. Aural volume can be controlled. G-M tube and probe may be ordered. (P-7)



Microvolt Signal Generator

Hickok Electrical Instrument Co., 10584 Dupont Ave., Cleveland 8, Ohio. The model 292X microvolt signal generator has ranges of 125 kc to 110 Mc and 150–220 Mc, all on fundamentals. Crystal accuracy is available for mobile bands of 152–162 Mc. Modu-



THE STORY OF A NEW SCIENCE

Can it help you improve your products?

PRESS OR SQUEEZE *piezo-electric* materials, and they generate electricity. Conversely, charge them electrically and they change in dimension.

The use of such materials, in conjunction with electronic circuits, has created a virtually new science . . . Piezotronics. Modern Piezotronic systems enable manufacturers of dictating equipment and hearing aids to streamline their products. They help the Navy detect submarines, and inspectors detect flaws in materials. They provide a "memory" for computing machines, and a power source for users of ultrasonics.

Brush, the world's leading producer of man-made piezo-electric materials, has prepared this informative 24-page booklet describing Piezotronics, its many functions, and its broad application. Mail this coupon now for your copy of "Piezotronics". . . it may spark the product-development idea you have been looking for.

BRUSH ELECTRONICS COMPANY

INDUSTRIAL AND RESEARCH INSTRUMENTS
PIEZOELECTRIC MATERIALS • ACOUSTIC DEVICES
MAGNETIC RECORDING EQUIPMENT
ULTRASONIC EQUIPMENT

BRUSH 6 ELECTRONICS

formerly
The Brush Development Co.
Brush Electronics Company
is an operating unit of
Clevite Corporation.

Please send me
FREE COPY
of 24-page illustrated booklet
"PIEZOTRONICS"

BRUSH ELECTRONICS COMPANY, DEPT. 1T-3
3405 PERKINS AVENUE • CLEVELAND 14, OHIO

Name _____
Company _____
Title _____
Address _____
City _____ *State* _____

Want more information? Use post card on last page.

What's new in radiation research?

Perhaps *you* could tell *us* a thing or two! If so, you're just the kind of man who can benefit most from our 38 years of research in radioactivity. We suggest you investigate these recent U. S. Radium developments:

Radiation Sources

The United States Radium Corporation produces the following types of radiation sources:

Alpha	Alpha-beta-gamma
Beta	
Gamma	
Neutron	Beta-gamma

Radium — Radium D — Polonium
Uranium Oxide — Isotope

Alpha, Beta, and Gamma Ray Sources

For your research or experimental requirements, U. S. Radium Corporation can provide appropriate sources of alpha, beta, or gamma radiation – in foil, strip, or point form. Sources suitable for ionizing air or other gases, for indirect activation of phosphors, and for many other applications can be supplied.

Standard Light Sources

Radioactive luminous compounds requiring no external source of activation, exhibiting virtually negligible change in brightness with time, and emitting only easily absorbed radiations, have been developed by U. S. Radium Corporation. The colors available cover most of the visible spectrum.

Neutron Sources

Calibrated or Uncalibrated

Radium-Beryllium
1 to 1000 millicuries

Polonium-Beryllium
1 to 5000 millicuries

Radium D-Beryllium
1 to 100 millicuries

Let's Work Together

With these and related products, U. S. Radium Corporation is serving the exact needs of research, industry, and medicine. Our laboratories provide both standard and special materials – some of them available nowhere else. Our scientists will work with you to meet your requirements in this field.

FREE FOLDER: We've prepared a four-page folder that describes the activities of the U. S. Radium Corporation. If you'd like a copy of our most recent issue – and future copies as they are issued – just write for "Radiations N-3"

UNITED STATES RADIUM CORPORATION
535 Pearl Street — New York 7, N. Y.

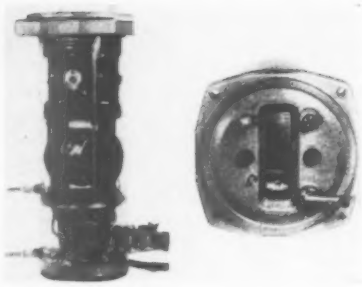
lated and unmodulated output is provided from 0.2 to 100,000 μv; external modulation from 15 to 10,000 cps is possible. Audio-frequency output is 0–2 volts at 400 cycles. (P-8)

Pyrometer-Millivoltmeter

Thermo Electric Manufacturing Co., 480 Huff St., Dubuque, Iowa. Long thermocouple leads of this portable combination pyrometer and millivoltmeter permit temperature checkings 8 ft from the instrument. Three ranges are calibrated in Fahrenheit, Centigrade and millivolts: 800° F, 430° C, 17 mv; 1,600° F, 865° C, 36 mv; 2,250° F, 1,225° C, 50 mv. Accuracy is within 1%. (P-9)

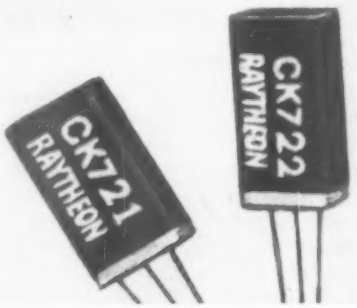
Square Wave Generator

New London Instrument Co., Box 189, New London, Conn. The type 150-A generator provides square waves from 50 cps to 1 Mc with a maximum rise-time of 0.05 μsec. Fixed frequencies are 50, 1,000, 10,000, 100,000, and 1,000,000 cps. Other frequencies are obtainable with a frequency-control capacitor. A pulse for oscilloscope synchronization is available. Output is controllable from 0–20 volts, peak to peak. (P-10)



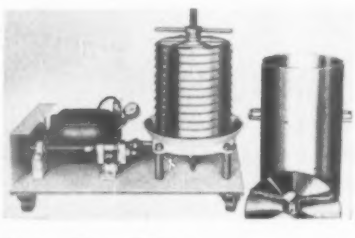
Pressure Meter

Fischer & Porter Co., Hatboro, Pa. The Press-I-Cell measures pressure with an accuracy of 1 part in 5,000 and has a sensitivity of 1 part in 15,000. Typical ranges are 1 atmosphere absolute, 400-in. water column, and 150-in. Hg differential. An interval of $\frac{1}{16}$ in. on the 50-ft scale represents 1/10,000 of full pressure range. Manual or automatic models are available. Dimensions are 5-in. diameter and 14-in. length. (P-11)



Germanium Transistors

Raytheon Mfg. Co., Receiving Tube Div., 55 Chapel St., Newton 58, Mass. The types CK721 and CK722 *pnp* germanium junction transitors provide gains of 38 db and 30 db, respectively. Their noise factors average 22 db at 1,000 cycles. Both are rated (absolute maximum values) at −20-volt collector voltage, −5-ma collector current, and 5-ma emitter current. (P-12)



Down-Flow Filter

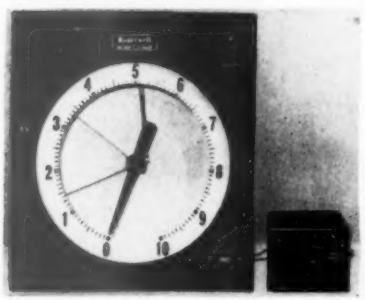
Ertel Engineering Corp., Clinton Ave., Kingston, N. Y. The model ECF

Want more information? Use post card on last page.

filter is a center-feed unit. Its down-flow filtration builds up a uniform filter cake which will not part from the screens. The amount of unfiltered material is only that contained in the center-feed pipe. Independent tightening of the filtering elements provides a positive seal and allows the use of various types of filter media. Capacity is 2–20 filter sheets; filter capacity can be varied with spacer collars. This model is normally made in stainless steel. (P-13)

Electrical Leakage Tester

Peschel Electronics, Inc., 13 Garden St., New Rochelle, N. Y. This audio continuity and leakage tester checks circuits from zero to 100 megohms. Sensitivity is 1-μa leakage current. It is claimed not to injure low-current components. Other uses are: surface-conductivity measurement, fluid-level indication, and approximate resistance indication. (P-14)



Electronic Flow Meter

Minneapolis-Honeywell Regulator Co., Industrial Division, Philadelphia 44, Pa. The Potter-Brown flow meter consists of a sensing element, installed in the flow stream, whose a-c output frequency is directly proportional to rate of flow; a converter; and a poten-

An Isotronic* First

±0.01% AC REGULATION!

That's the degree of accuracy attained by Sorensen's new Model 1001 AC Line Voltage Regulator!

Heretofore, the closest regulation in commercially available regulators has been ±0.1%, regardless of manufacturer or circuit approach. Now, Sorensen's continuing study and design refinements have produced a super-accurate regulator – the model 1001 – as a *standard* catalog item.

GENERAL SPECIFICATIONS

Load range	0 – 1000 VA
Input voltage range	95 – 130 VAC, 1φ, 55 – 65~
Load P. F. range	0.7 lagging to 0.95 leading
Output voltage	115 VAC, 1φ (adjustable from 110-120 volts)
Distortion	3% max.
Time constant	0.1 seconds
Regulation accuracy	±0.01%

The accuracy is *guaranteed* at room temperature, for a resistive load, an input variation of ±10%, and over a two-to-one load change. For *all* other conditions within the specifications, the Model 1001 has a proportionate amount of accommodation.

Model 1001

Note these extra features

- Combination twist-lock and double-T receptacle, or, output terminals to eliminate contact resistance.
- Three-function output switch for
  1. Normal regulator functioning.
  2. Operation with integral semi-fixed resistance in place of potentiometer.
  3. Direct load connection with the control diode for regulation of voltages other than 115 volts.
- Only FOUR vacuum tubes and NO relays are used.
- All tube filament voltages are regulated for long dependable life.

WRITE FOR FULL INFORMATION

*Isotronics is a trade marked word pertaining to the electronic regulation and control of voltage, current, power, or frequency.

FOR THE LATEST AND BEST IN ISOTRONICS:

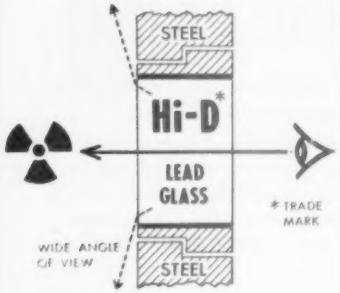
Specify SORENSEN

375 FAIRFIELD AVENUE • STAMFORD 3, CONNECTICUT

Hi-D*

LEAD GLASS WINDOWS

IN STEEL WALLS



Hi-D Lead Glass Windows provide clear, direct, wide-angle, binocular vision through heavy gamma-shielding walls. Lead equivalent 0.55; steel, 1.0

Send for circular G S

PENBERTHY INSTRUMENT CO.
606 ADAMS ST. • SEATTLE 8, WASH.

Get It... Use It!

Your Helping Hand..

NEWEST... GREATEST *Most Complete* BUYING GUIDE *For All Standard Electronic Equipment!*

FREE! 1953 **HUDSON CATALOG..**

. . your helping hand for Everything in Electronic Equipment. Over 196 pages of the latest in Radio, TV and Industrial Electronics. High Fidelity and PA Sound Equipment PLUS JAN type Electronic Components with latest JAN Cross-Reference Guide. Send for your copy . . . KEEP IT HANDY for ordering . . . It's Quick, Convenient . . . Time and Money Saving! . . . ONE Dependable Source — **ONE Call for ALL!**

When you attend the **IRE SHOW**, you're invited to visit our uptown salesroom, adjoining Radio City . . . **only 4½ blocks from Grand Central Palace!** Open until 9 P.M. during show time, March 23-26.

HUDSON RADIO & TELEVISION CORP.

Send for FREE Catalog to Dept. AA-3

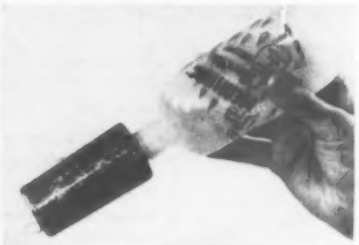
48 WEST 48th ST. • 212 FULTON ST.

New York 36, N. Y. • Circle 6-4060 • New York 7, N. Y.

tiometer which indicates and records the converter d-c output. The unit handles toxic, highly corrosive, or viscous liquids at pressures up to 20,000 psi from 4° A to 1,200° F. Accuracy is claimed to be ±½% of full scale. (P-15)

Static Detector

Keithley Instruments, 3868 Carnegie Ave., Cleveland 15, Ohio. The model 2005 static detector clips onto a Keithley vacuum-tube electrometer, providing a combination for locating static charges. Qualitative results are obtained by noting the deflection of the meter pointer. Sensitivity can be varied by raising or lowering the inner tube. (P-16)



Water Demineralizers

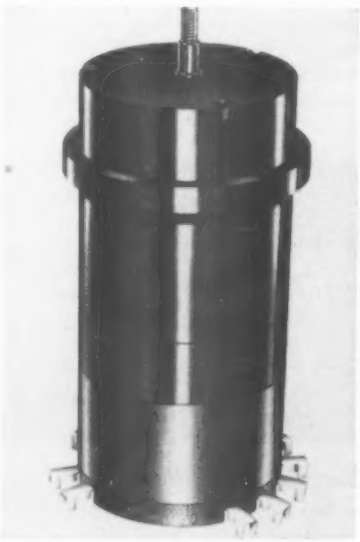
Win Sales Co., Dept. JL-1, Box 257, Forest Hills, N. Y. The Deeminac and Deeminizer water demineralizers are claimed to produce water as pure as that obtained by triple distillation. The method employs mixed-bed ion exchange resins. A hand unit consists of a flexible plastic bottle with plug-in resin filter top. A larger unit uses a meter to indicate water purity. (P-17)

Analog Recorder

Streeter-Amet Co., 4101 N. Ravenswood Ave., Chicago 13, Ill. This analog data recorder can be adapted to print numerical values of many analog quantities capable of being converted into a corresponding voltage with a sensing device such as a photocell. Components may be incorporated to perform multichannel operation, automatic-print actuation, time-index printing, and zero-balance adjustment. Other computing components may be added. (P-18)

Magnetic Pipe Plugs

Magnetic Drain Plug Co., Wellington, Ohio. Magnetic pipe, drain, and filler plugs, from ⅛ to 2 in., are made with square, square countersunk, hexagon countersunk, slotted, and hexagon heads. They are made of cast iron, steel, malleable, brass, aluminum and stainless steel. All plugs are threaded "dryseal." The Alnico magnets attract 10 times their weight directly from the liquid stream. (P-19)



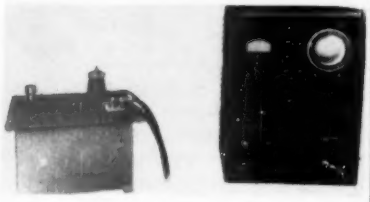
Electrical Resolver Systems

Ford Instrument Co., 31-10 Thomson Ave., Long Island City 1, N. Y. The sizes 23 and 31 resolver systems, de-

signed for computers, consist of a resolver, high-gain amplifier, and summing network box. They operate in the range −60 to +160° F; standardization allows interchangeability of components; choice of network boxes and amplifiers provides flexibility. Up to two electrical and one mechanical, or two mechanical and one electrical, inputs can be used. Typical specifications are 400 cps with a maximum input of 0.25—12.0 volts and an input impedance of 1.0 megohm. (P-20)

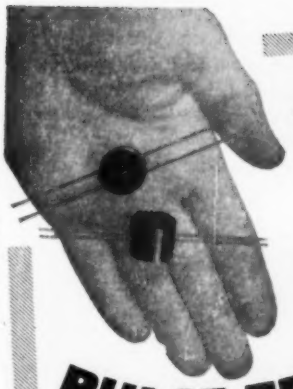
Universal Potentiometer

G. M. Giannini & Co., Inc., 117 E. Colorado St., Box N, Pasadena 1, Calif. The model 85196 universal potentiometer is available in single-section units with syncro-type or screw-type mounting. Both sleeve-bearing and ball-bearing models are made; torque is 0.5 oz-in. for the latter. Standard linearity tolerance is ±0.3%. Mechanical rotation can be 360 degrees, continuous, or stops can be provided for any rotation up to 330 degrees. The standard electrical contact angle is 356 degrees. Resistances from 2,000 to 200,000 ohms are available. (P-21)



Corona Ionization Detector

Network Mfg. Corp., 213 W. 5th St., Bayonne, N. J. This corona ioniza-



LOOK WHAT'S NEW!

MADE TO YOUR SPECIFICATIONS

TECHNITROL *Type* TE

PULSE TRANSFORMERS

SEALED IN CASTING RESIN

NOW YOU CAN SIMPLIFY AND MINIATURIZE YOUR SHORT-PULSE CIRCUITS

Currently available in one physical size—3/4" diam x 9/16" deep, with 2" leads of No. 20 wire—made to your order within the following range of specifications.

Pulse Width	0.1 to 2.0 microseconds
Maximum Pulse Repetition Rate:	2.0 mc.
Operating Range	−55° to +105°C.

One or two secondaries may be provided, either inverting or non-inverting.

WRITE US YOUR SPECIAL REQUIREMENTS including a brief outline of the contemplated circuit, or ask for our blank specification sheets.

LOOK AT THESE PRICES!

1 to 3	$7.50 each
4 to 10	6.35 each
11 to 100	5.85 each

Write us for quotations for quantities over 100

TECHNITROL ENGINEERING COMPANY

2751 North 4th Street, Philadelphia 33, Pa.

See us at the IRE Show—Booth 4-107

For the First Time Anywhere

POWER SUPPLIES WITH REGULATION AND STABILITY

MEASURED IN

PPM

PARTS PER MILLION

SERIES 400

ESPECIALLY FOR NUCLEAR WORK

- Regulation—100 PPM for line voltages 105V to 130V.
- Load Regulation—75 PPM from no load to full load.
- Stability—100 PPM for 3 hrs./500 PPM per day.
- Ripple—better than .01%—(negligible noise and bounce.)
- Transient—free for all line disturbances.
- For more stable than batteries.
- Minimum warm-up time.

SPECIFICATIONS

Model 400B.	1000 to 5000 V.,	0–1 MA. Negative side grounded.
Model 400C.	500 to 1500	0–1 MA. Negative side grounded.
Model 400D.	1000 to 5000	0–1 MA. Positive side grounded.
Model 400E.	500 to 1500	0–1 MA. Positive side grounded.

Models to your specific voltage requirements available on order.

Also

For wider voltage range and for higher output current, for even greater stability and for regulation to 20 PPM, we offer the 300 Series Precision Direct Current Power Supplies—Catalog literature available on request to Dept. NF-12.

JOHN FLUKE ENGINEERING COMPANY

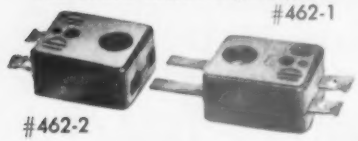
1111 W. NICKERSON STREET
SEATTLE 99, WASHINGTON

Represented by Burlingame Associates—New York, Boston, Wash., D. C.; Hugh Marsland & Co.—Chicago, Gerald B. Miller Co.—Hollywood, San Francisco, Albuquerque; M. P. Odell Co.—Cleveland, Dayton; James L. Kearns—Portland, Ore.; Earl Lipscomb Assoc.—Dallas; H. M. Richardson & Co.—Minneapolis.

From Alden's Line of Ready-made Components for Unitized Plug-in Unit Construction:

No more blind connectors

#462-1

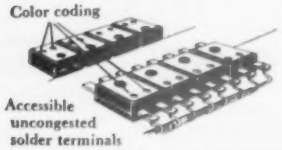


#462-2

ALDEN PATENTED

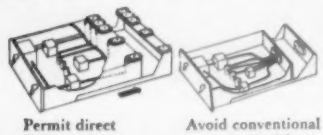
BACK CONNECTORS

Get accessible central check point for incoming and outgoing leads



EASY SERVICING AND RAPID CIRCUIT CHECKS

Solder terminals easily accessible and uncongested for multiple contact wiring. Color-coding on back connector, corresponding to lead color, identifies each lead for instantaneous check to main circuit or trunk line.

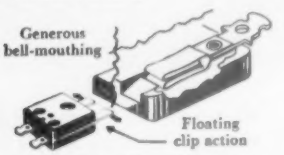


Permit direct efficient wiring

Avoid conventional rats nest wiring

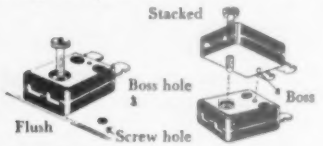
EFFICIENT CIRCUIT WIRING

Connectors can be mounted where desired — to allow for isolation of critical voltages or frequencies — to provide most direct wiring from component to connector — to eliminate rat-nest wiring of conventional methods.



EASY INSERTION AND REMOVAL

Made possible by large bell-mouth entries and ample float of rugged live-action beryllium copper contacts. Wide mating tolerances eliminate critical unit alignment problems.



EASY MOUNTING

Single screw for mounting flush or stacked. Molded locating boss positions and locks connector in place on unit when flush mounted — boss accurately lines up and positions connectors together in stack mounting.

SEND FOR FREE SAMPLES

— also request free "Alden Handbook" 226 pages of techniques and components for Unitized Plug-in Unit Construction.

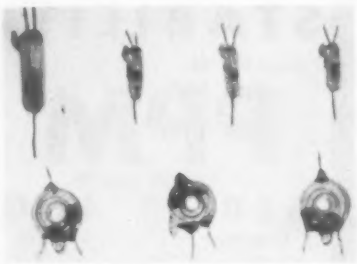
NA-ALO ALDEN PRODUCTS CO.

147 N. Main St., Brockton 64, Mass.

tion detector is designed for testing corona initiation and extinction levels in coaxial cables, transformers and other insulated electrical components. It is useful for study of dielectrics before rupture by breakdown and for nondestructive testing. (P-22)

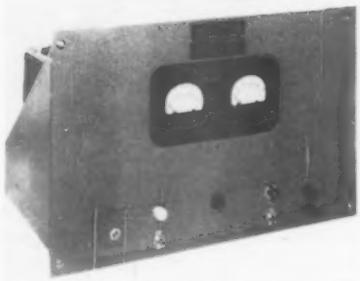
Telereader

Telecomputing Corp., 133 E. Santa Anita Ave., Burbank, Calif. The Universal Telereader is an aid to making measurements from records ranging from 16 and 35 mm film to 12-in. oscillograph paper up to 100 ft in length. It can handle either translucent or opaque records. Three interchangeable projection lenses permit record magnification of 2×, 4× and 11×. With auxiliary equipment, measurements can be printed in decimal form or punched on cards. (P-23)



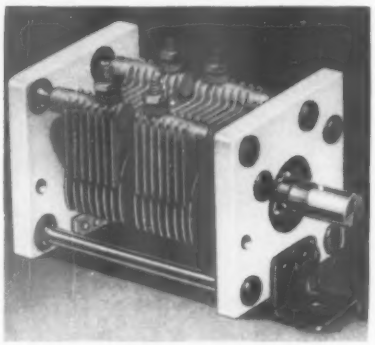
Mercury Switches

Kahl Scientific Instrument Corp., Box 1166, El Cajon, Calif. These miniature mercury switches and tilt-type resistance-wire switches use eutectic mercury with a freezing point of −80° F. They are available in Pyrex and have nonfracturable evacuation tips. Tungsten electrodes can be supplied for high-temperature work and can be furnished copper plated for direct soldering of leads. Multitime delay action can be obtained. (P-24)



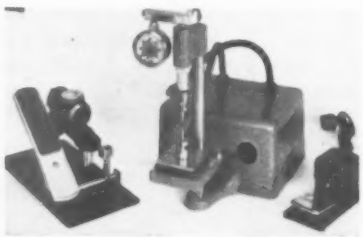
Regulated B-Supply

Sorensen & Co., Inc., 375 Fairfield Ave., Stamford, Conn. The model E-300-1 B-supply has an adjustable output of 297–303 volts, d-c, at 0–1 ampere. Regulation accuracy is ±1% for line and load changes from zero to full load; ripple is 10 mv. Input required is 105–125 volts at 50–60 cycles. (P-25)



VHF-UHF Capacitor

Hammarlund Mfg. Co., Inc., 460 W. 34th St., New York 1, N. Y. The VU variable capacitor operates at 50–500 Mc. Two capacitor sections in series eliminate the need for rotor contacts. Pyrex ball bearings eliminate contact and bearing noise. (P-26)



Spot Welder

Stewart Engineering Co., Box 145, Soquel, Calif. This spot welder is designed for making welds on vacuum tubes and for assembly of metal parts of a precise nature. The top electrode is hydraulically actuated by a foot pedal; a separate foot switch can be

Versene*

. . . Decontaminating Agent for Radioactive Deposits

Once anything has been made radioactive, there is no way to destroy this radioactivity. But, radioactive contamination which is usually a deposit of insoluble compounds (metallic oxides) can be solubilized (chelated) with *Versene* and washed away with large volumes of water. This results in great dilution and removes the danger. For deposits on exposed surfaces the addition of a good detergent formulation is recommended. In living organisms *Versene* has been used experimentally to detoxify heavy metals and to help remove radioactive deposits. Send for sample. Write Dept. I for Technical Bulletin No. 2. Chemical counsel available on request.

*Trade Mark Registered

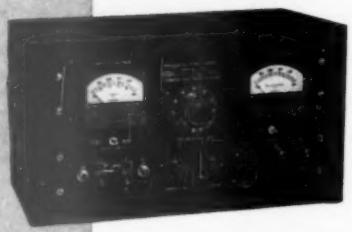
KEY TO CHELATION

"Chemistry's most precise chemicals"

BERSWORTH CHEMICAL CO.
FRAMINGHAM, MASSACHUSETTS

ELECTRONICALLY REGULATED

LABORATORY POWER SUPPLIES



BENCH MODEL 50

• STABLE
• DEPENDABLE
• MODERATELY PRICED
•

ALSO AVAILABLE STANDARD RACK MOUNTING

MODEL 50-R PANEL SIZE 10½" x 19" DEPTH 14½"

- **INPUT:** 105-125 VAC, 50-60c
- **OUTPUT #1:** 0-500 VDC at 500 ma regulated
- **OUTPUT #2:** 0-50 VDC, 0-200 VDC Bias Output.
- **OUTPUT #3:** 6.3 VAC at 5A unregulated
- **OUTPUT #4:** 6.3 VAC at 5A unregulated
- **RIPPLE OUTPUT:** Less than 8 millivolts rms

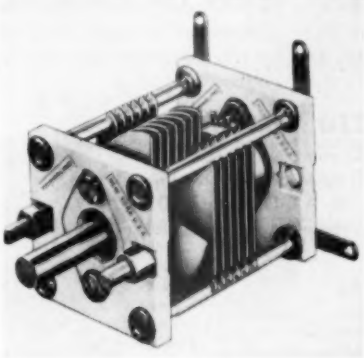
For complete information write for Bulletin N

LAMBDA ELECTRONICS
CORPORATION
CORONA NEW YORK

used, if desired, as an interlock. Pressure of the electrodes on the work is read on a gage which also acts as a pressure-operated switch; a movable secondary hand on the gage sets the closure pressure of the switch from 2 to 60 lb. (P-27)

Globe Valve

George W. Dahl Co., Inc., Bristol, R. I. The model DEMI-G globe valve, packless and tamper proof, is designed for hydraulic, pneumatic, or vacuum use. Brass and aluminum valves handle pressures up to 1,500 psi; for higher pressures, valves are made of steel, stainless steel, Monel, and nickel. They can be applied to oil, gas, and corrosive systems. (P-28)



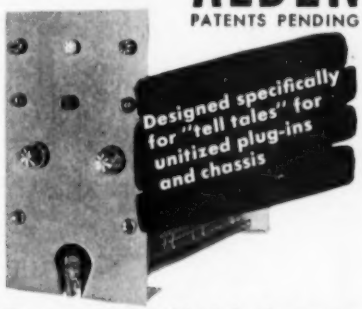
High-Speed Capacitor

Hammarlund Mfg. Co., Inc., 460 W. 34th St., New York 1, N. Y. This butterfly-type variable capacitor, designed for applications requiring alternating capacity values, is capable of continuous operation at up to 3,200

From Alden's Line of Ready-made Components for Unitized Plug-in Unit Construction:

Miniature Sensing and Indicating Components by ALDEN

PATENTS PENDING



The new trend to unitized plug-in construction calls for tiny sensing and monitoring devices to act as "telltales" when trouble occurs. Device must be rugged, yet take a minimum of panel space. Here are latest in Alden Series to meet this problem.

ALDEN "PAN-i-LITE"

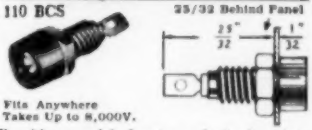
86L
Mounts in .348" hole
Quickly replace built from front of panel
Bulb and Lens are 1 pc. instantly replaceable with unbreakable spares.

You can use this new tiny Alden Pan-i-Lite indicator where never before possible. Easily serviced one-piece lens-bulb replaceable from front of panel. Mounts simply by pushing into .348" hole. Gives beautiful indication; glows like a red hot poker. Tiny spares can always be kept ready in kit or taped in recess of equipment. Available in 6V, 12V and 28V, various colors.

ALDEN "FUSELITE"

Spot trouble instantly. Neon indicator light in lens glows when fuse blows. One-piece molded lens-and-indicator-lite unscrews from front of panel. Ideal for monitoring power to each unitized circuit. Available for 28V, 110V and 250V.

ALDEN TEST POINT JACK



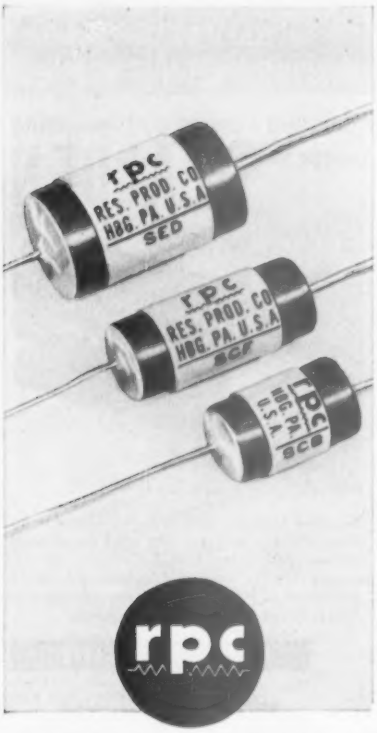
Provides a quick front panel check point for any circuit voltages in your equipment. This tiny Jack fits .257" hole and takes only 25/32" behind panel. Beryllium copper contact withstands hundreds of insertions. Phenolic or nylon insulation, many colors.

SEND FOR FREE SAMPLES

— also request free "Alden Handbook" 226 pages of techniques and components for Unitized Plug-in Unit Construction.

ALDEN PRODUCTS CO.

147 N. Main St., Brockton 64, Mass.



MINIATURE HERMETICALLY SEALED PRECISION WIRE WOUND

Where the utmost in permanence and stability are required, Type S has proven successful. Unaffected by extreme temperature cycling, aircraft altitude or salt water immersion.

Wound on steatite forms, solder sealed into steatite jackets. Vacuum tested. Long leakage path. Can be wired into circuit. Self supporting. Low coefficient alloys used.

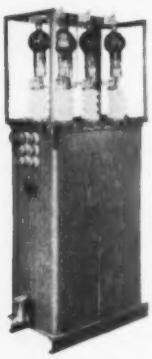
Standard resistance tolerance 1%. ½% and ¼% also available. Write for complete information and engineering data.

TYPE	DIMENSIONS Leng.	Diam.	JAN-R-93	POWER RATING (watts) JAN.	Comm.	RESISTANCE Min. (ohms.)	Max. (meg.)
SCB	9/16	1/32	—	—	1/4	2.0	0.15
SCF	13/16	11/32	RB51A	1/4	1/2	1.0	0.40
SED	13/16	15/32	RB51A	1/4	1/2	0.5	1.0

RESISTANCE PRODUCTS CO.

714 RACE STREET HARRISBURG, PA.

For HEAVY DUTY HIGH VOLTAGE MAGNATRAN®



34 KW 17,000 V.D.C.

PRODUCTS ARE BETTER*

YES . . . WE BUILD BETTER EQUIPMENT BASED ON MANY YEARS OF EXPERIENCE

*While this word has been overworked in many instances, we will be pleased to demonstrate the extras built into our transformers to make them better.

⇐ NEW UNITIZED RECTIFIERS

For high voltage D.C. sources . . . lower initial cost . . . minimum upkeep . . . convenient — ready to connect to A.C. line and D.C. load . . . compact — requires minimum floor space.

Askarel Immersed Filter Reactor 50,000 Volt Test

AIR . . . OIL . . . ASKAREL

Plate Transformers . Filament Transformers . Filter Reactors . Modulation Transformers . Distribution Transformers . Pulse Transformers . Testing Transformers . Precipitation Transformers . General Purpose Transformers . Hi-Voltage Transfomers.

WRITE FOR DETAILED INFORMATION

MEETS STANDARDS OF AIEE-NEMA

A NAME SYNONYMOUS WITH EXPERIENCE

MAGNATRAN INCORPORATED

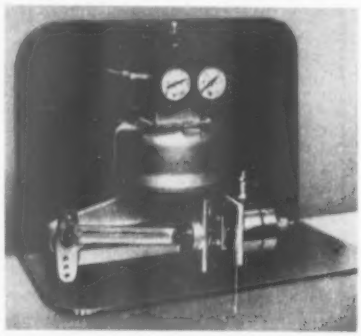
TRANSFORMERS AND ELECTRICAL EQUIPMENT

WALTER DARLICK, JR., PRESIDENT

246 SCHUYLER AVE., KEARNY, NEW JERSEY

MAGNATRAN®

rpm. Ball bearings are used in place of rotor contact springs. Series effective-capacity values range from 5.4 to 17.0 μf, nominal. (P-29)



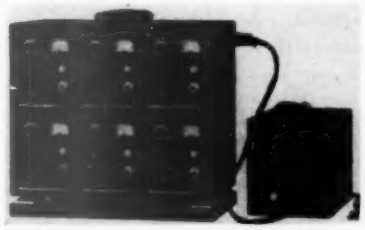
Flow-Control Valve

Annin Co., 3500 Union Pacific Ave., Los Angeles, Calif. The pneumatically controlled Wee Willie valve is available with standard working-pressure ranges of 10,000 and 30,000 psi, with special assemblies up to 50,000 psi. Sizes range from ⅛ in. through ½ in. with screw, welding, superpressure, and autoclave-end connections available. A combination of four interchangeable plugs and two seat rings provides a C_v selection of 0.0016–1.00. Flow characteristics are normally linear. Various valve-body materials are available on order. (P-30)

Electrical Meters

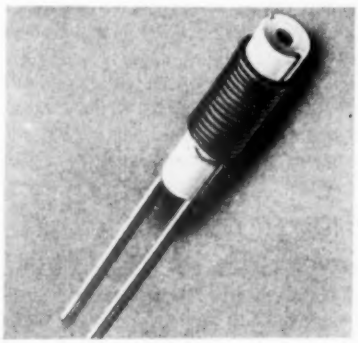
Phaostron Co., 151 Pasadena Ave., S. Pasadena, Calif. These ruggedized, hermetically sealed electrical indicating instruments are available as d-c and a-c voltmeters and d-c milliammeters. Each meter has five full-scale ranges with only the selected scale visible. The ranges are: for 1,000 and 20,000 ohms/volt d-c voltmeters, 2.5, 10, 50, 250, 1,000 volts; for a-c voltmeter, 10, 50, 150, 500, 2,500 volts; for d-c micromilliameter, 250 μa,

1 ma, and 10, 100, and 500 amperes. Accuracy is 1% full scale. (P-31)



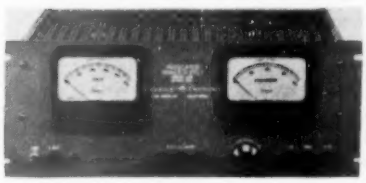
Portable Amplifier

Yellow Springs Instrument Co., Inc., Box 106, Yellow Springs, Ohio. The model 201-A six-channel portable amplifier consists of six individually excited, single-channel amplifiers and a regulated power supply. Maximum undistorted amplifier output is 1.2 volts, rms, with an impedance of 250k ohms; amplification is 4,000. A toggle switch permits each channel to furnish amplified output or integrated and amplified output. Power-supply output is 300 volts, d-c. (P-32)



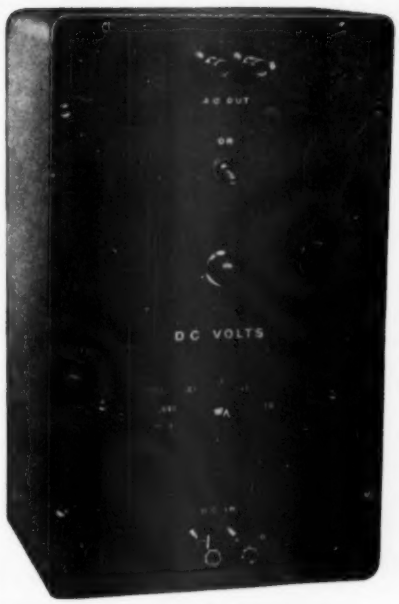
Instrument Resistor

Shallcross Mfg. Co., 10 Jackson Ave., Collingdale, Pa. The type 2458 1-watt, wire-wound resistor is designed for decades and other low-resistance uses. The resistor can be calibrated to a tolerance of ±0.1% and is available from 0.1 to 1,000 ohms. A single-layer bifilar winding is protected by lacquer coating. (P-33)



Regulated Power Supply

Universal Electronics Co., 2012 S. Sepulveda Blvd., Los Angeles 25,



MODEL 200-A DC MILLIVOLTMETER

Used by leading laboratories throughout the industry

DC Measurements

5 MICROVOLTS to 10 VOLTS

A precision converter, that changes the input DC into an amplified, sinusoidal AC Voltage.

- 5 microvolts internal noise
- Max. gain 1000 (volts RMS/volt DC)
- 40 millisecond time constant
- No zero or gain adjust
- 2 megohm input resistance
- Rejects external 60 cps pickup

Makes any AC Vacuum tube Voltmeter direct reading in DC microvolts and millivolts.

With the cathode ray oscilliograph yields an extremely sensitive DC null detector.

ICCO INDUSTRIAL CONTROL COMPANY

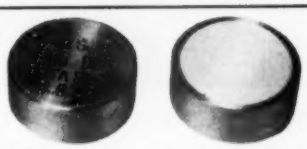
Wyandanch Long Island, New York

From the
Tiny Air Cooled OFEC #A100
OIL DIFFUSION PUMP
to the
INDUSTRIAL SIZE 10" PUMP

We cover the range of High Vacuum Equipment. See us for pumps, complete pumping systems, evaporators, furnaces and accessories.

OPTICAL FILM ENGINEERING COMPANY

2731-37 North 6th Street • Philadelphia 33, Pa.



CALIBRATION SOURCES AND ABSORBERS

ALPHA, BETA & GAMMA STANDARDS for calibration and/or normalization of radiation detectors.

SPLIT SOURCES for estimation of coincidence loss in counting tubes and equipment. Active material is evenly distributed over a 22 mm circle centered on the top face of a 1" d × 3/8" high brass disc. Each source is individually calibrated and engraved with true disintegration rate, active material, and date.

ABSORBERS A series of 25 Aluminum and 5 lead absorbers comprises each set. Thicknesses are chosen to give smooth absorption curves with no dead spaces. Ideal for Beta curves and soft X- or gamma plots. Diameter of absorbers is 1 7/8". Each disc is individually calibrated, marked and housed in walnut case.

ISOTOPES SPECIALTIES CO., INC. 3816 SAN FERNANDO RD., GLENDALE 4, CALIF.

SCINTILLATION CRYSTALS

Shipped promptly
From stock of finest quality

ANTHRACENE
STILBENE
DIPHENYL-ACETYLENE
p-TERPHENYL
SODIUM IODIDE
SINTILON BRAND OF SCINTILLATION PLASTIC

First choice of many research labs, National Radiac crystals are guaranteed to be the finest possible.

Send for special bulletin

National Radiac

Dept. N-4
10 CRAWFORD STREET
NEWARK 2, N. J.

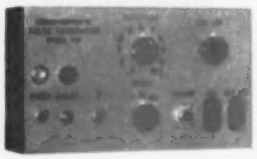
Announcing the Model 401

PULSE GENERATOR

Featuring Versatility and Precision

at the low cost of $125.00 FOB Plant

SPECIFICALLY DESIGNED for the NUCLEAR PHYSICS LABORATORY

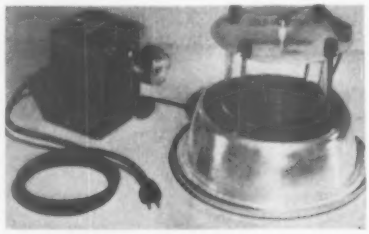


FAST RISE AND EXPONENTIAL DECAY SIMULATES SCINTILLATION, PROPORTIONAL OR GEIGER COUNTER PULSES FOR TEST AND CALIBRATION OF AMPLIFIERS, PULSE HEIGHT ANALYZERS, SCALERS, ETC....

Rise time: less than 0.003 microsecond.
Decay time: selector switch for 1, 10 or 100 microsecond RC decay
Pulse amplitude: 1 mV to 1 V in 10 steps (from internal supply)
Provision for external battery for pulses up to 45 Volts (continuously variable).
Provision for calibration by external potentiometer.
Polarity switch permits selection of positive or negative pulses.
Output contains only pulses of desired polarity.
Western Electric mercury relay. Repetition rate 3600 ppm.
Precision Resistors throughout for high accuracy and stability.
Stable mercury cell, protected by AC relay, lasts for shelf life.

RADIATION INSTRUMENT CO.
P.O. BOX 733 SILVER SPRING, MARYLAND

Calif. The model 32A regulated power supply furnishes 160–325 volts, d-c, at 0–200 ma; either positive or negative output terminal may be grounded. Unregulated output is 6.3 volts, a-c, at 8 amperes. Regulation is better than ½% from no load to full load, or for line-voltage fluctuations from 105 to 125 volts. (P-34)

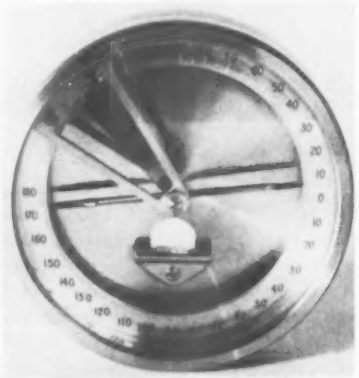


Demonstration Cloud Chamber

Nuclear Instrument and Chemical Corp., 229 W. Erie St., Chicago 10, Ill. The model 1413 cloud chamber demonstrates radiation tracks through saturated alcohol vapor within a glass chamber. Alpha and beta particles are supplied from a small radium source which is claimed to be entirely safe to handle. The power supply includes an illuminating spotlight. The unit operates from any 110-volt, 60-cycle power supply. (P-35)

Electrostatic-Charge Detector

Herman H. Sticht Co., Inc., 27 Park Place, New York 7, N. Y. The Statigun, for measuring electrostatic charge, operates on the principle that a small voltage, proportional to that being measured, is induced by capacitive coupling onto the grid of an electrometer tube; the tube's anode current is measured in terms of volts per foot. The instrument is scaled up to 2,000 volts/ft; an adjustable sleeve gives readings 1, 10 and 100 times scale reading. Accessories permit charge measurement (1×10^{-9} to 3×10^{-8} coulomb/cm²) and resistance measurement (10^7–10^{13} ohms). (P-36)



Dip Needles

Radiac Co., Inc., 489 Fifth Ave., New York 17, N. Y. The model D-2 dip needle and the self-orientating dip needle, nonelectronic magnetic instruments, define areas of high magnetic characteristics, such as magnetic ores or artifacts. The model D-2 is designed for rugged use, while the self-orienting dip needle is for fast traversing where disturbing factors are not expected to be too great. (P-37)

INDUSTRY NOTES

▶**Westinghouse Electric Corp.,** 229 W. Erie St., East Pittsburgh, Pa., has orders for $10-million worth of high-efficiency electric motors for AEC projects. A "sizable number" has already been delivered.

▶**Consolidated Engineering Corporation,** 300 N. Sierra Madre Villa, Pasadena 8, Calif., has purchased Eastman Kodak's Distillation Products Industries. The new company, Consolidated Vacuum Corp., will remain in the Rochester area.

▶**Radiation Counter Laboratories, Inc.,** 5122 W. Grove St., Skokie, Ill., has appointed Edwin R. Rathbun, Jr., as director of physical research. Mr. Rathbun was formerly with Nuclear Instrument and Chemical Corp. and the AEC laboratory at Ames, Iowa.

▶**Nuclear Engineering Co.,** 1369 Fourth Ave., San Francisco 22, Calif., has received an AEC general authorization for radioactive waste disposal. Nuclear will provide the following

WHERE TO BUY

Larger Sizes Now Available
HI-D* LEAD GLASS WINDOWS
For use in steel, lead, and concrete walls.
*Trademark
PENBERTHY INSTRUMENT CO.
666-8 Adams St. Seattle 8, Wn.

SEARCHLIGHT SECTION
(Classified Advertising)
EMPLOYMENT • BUSINESS EQUIPMENT — USED OR RESALE
OPPORTUNITIES

UNDISPLAYED RATE
$1.50 a line. Minimum 3 lines.
DISPLAYED RATE
$15.00 per inch.
ADVERTISING INCH: ½" on one column, 3 columns—30 inches—to a page.
NEW ADVERTISEMENTS
Address: 330 W. 42nd St., New York 36, N. Y., for April issue closing March 27th.

BUILD IN WORLD NUCLEONICS CENTER
Metropolitan Oakland Area (MOA) home of the University of California and close to Stanford University, offers unmatched research or consultation facilities and personnel source for manufacturers, fabricators and marketers in nucleonics field. Besides its ideal location in shadow of two world-renowned research centers, MOA provides many additional, exclusive profit advantages to industry: proximity to users in great nucleonics center; geographic hub of multi-billion dollar West market; sizeable savings in shipping time and cost; major terminus for rail, truck, air, sea carriers; all-season production; temperate climate; acres of level plant sites, phenomenal, continuing G-R-O-W-T-H. For a Free FACTBOOK and/or answers to specific questions, write:
Alameda County New Industries Committee, Suite 801, 427 13th St., Oakland, Calif.

NUCLEONIC DESIGN ENGINEER
to take full charge of projects involving design and layout of nucleonic detection equipment. Write:
NUCLEAR RESEARCH CORP.
263 Grays Ferry Ave., Philadelphia 46, Pa.

This is where You should be, if You
- want employment
- are offering employment
- have used or surplus new equipment for sale, or want such equipment.

For information on how to reach the important men in the nuclear field—economically—write:
Classified Advertising Div.
Nucleonics
330 W. 42nd St., N.Y. 36, N.Y.

services: decontamination, consultation, film badges, and monitoring.

LITERATURE AVAILABLE

Pressure regulators. Catalog 29 describes constant-pressure differential regulator and instrument air pressure regulator. *Fischer & Porter Co., Hatboro, Pa.* (L-1)

Electric contact controller. Bulletin 850 describes controller for solenoid valves, warning signals and motors. *H. O. Trerice Co., 1420 W. Lafayette Blvd., Detroit 16, Mich.* (L-2)

Chromatography equipment. Pamphlet describes line of paper partition chromatographic equipment. *Research Equipment Corp., 1135 Third St., Oakland, Calif.* (L-3)

Nucleonic equipment. Illustrated price list for line of equipment and radiochemicals. *Tracerlab, Inc., 130 High St., Boston 10, Mass.* (L-4)

Analog computer. Catalog describes Computer Corp. of America's integro-differential analyzer and presents general theory of analog computers. *Burlingame Associates, 103 Lafayette St., New York 13, N. Y.* (L-5)

Analytical balances. "The Care and Use of Analytical Balances" discusses the basic fundamentals of general laboratory practice. *Torsion Balance Co., Christian Becker Div., Clifton, N. J.* (L-6)

Water stills. Bulletin 950 describes equipment for water distillation and storage. *Precision Scientific Co., 3737 W. Cortland St., Chicago 47, Ill.* (L-7)

Motors and timers. Specification sheet gives data on d-c motors and timers. *Amglo Corp., 2037 W. Division St., Chicago 22, Ill.* (L-8)

Contact meter-relay. Bulletin CMR-79 describes contact meter-relay with booster contacts. *Assembly Products, Inc., Main at Bell St., Chagrin Falls, Ohio.* (L-9)

X-ray spectrograph chart. Chart shows characteristic secondary X-ray beams for Na to U. *North American Philips Co., Inc., Research & Control Instruments Div., 750 S. Fulton Ave., Mount Vernon, N. Y.* (L-10)

High-voltage capacitors. Brochure describes a-c and d-c capacitors and pulse-forming networks. *Aircraft-Marine Products, Inc., 2100 Paxton St., Harrisburg, Pa.* (L-11)

The Latest in Improved
IRON SHIELDING
for real low level counting

DETECTOLAB'S MODEL DW2 illustrated is an Iron Shield that will take any commercial type mount and has a full two inches of shielding in all directions. Comes equipped with internal four hole probe connected to an external Amphenol 83-1R. New type hinged door is designed to reduce stray radiation. Instrument is finished in hospital white, acid-resistant baked enamel that is easy to decontaminate. Ideal low cost shield for Universities, Hospitals, and General Laboratories.

PRICE $169.00
FOB Chicago, Ill.
WRITE FOR FREE CATALOG OF NEW INSTRUMENTS
DETECTOLAB, Inc.
General Laboratory Offices
6544 North Sheridan Road, Chicago 26, Illinois

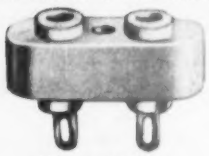
A copy of this quick-reading, 8-page booklet is yours for the asking. It contains many facts on the benefits derived from your business paper and tips on how to read more profitably. Write for the "WHY and HOW booklet."

McGraw-Hill Publishing Company, Room 2710, 330 West 42nd St., New York 36, N. Y.

Answer to VHF, UHF and Microwave Requirements

7-PIN MINIATURE TUBE SOCKETS

9-PIN MINIATURE TUBE SOCKETS



CRYSTAL SOCKETS

9-PIN CONNECTORS

STAND-OFF INSULATORS

FEED-THROUGH INSULATORS AND TERMINALS

TEFLON* INSULATED CHEMELEC COMPONENTS

- **LOW LOSS FACTOR** — Less than 0.0005.
- **STABLE DIELECTRIC CONSTANT**—2.0 (60 cycles to 30,000 megacycles).
- **HIGH SURFACE RESISTIVITY**—3.5 x 10^{13} ohms. Won't carbonize under arcing or DC plate.
- **WIDE SERVICE TEMPERATURE RANGE** —110° F to +500° F.
- **ZERO WATER ABSORPTION**—ASTM Test.
- **DURABLE** — withstands thermal and mechanical shock and vibration in assembly and service.
- **CHEMICALLY STABLE**—Inert, non-gassing, immune to corrosive atmospheres, fungi, oils, solvents.

Write for Catalogs: Miniature Tube Sockets, No. SO-428; 9-pin Connectors, No. CN409-M; Crystal Sockets, No. CS-441; Stand-off Insulators, No. TE-401; Feed-Through Insulators and Terminals, No. CF-400.

UNITED STATES GASKET COMPANY

FLUOROCARBON PRODUCTS DIVISION
CAMDEN 1, NEW JERSEY

Representatives in Principal Cities Throughout the World

*du Pont's trademark for its tetrafluoroethylene resin.

INDEX TO ADVERTISERS

March, 1953

Advertising Council	59
Alden Products Co.	82, 83
Allen-Bradley Co.	75
American Phenolic Corp.	66
Atomic Instrument Company	Third Cover
Barsworth Chemical Co.	83
Brush Electronics Company	77
Cambridge Instrument Co., Inc.	72
Chicago Transformer, Div. of Essex Wire Corp.	73
Cole Ltd., E. K.	4
Consolidated Engineering Corp.	Second Cover
Detectolab, Inc.	87
Fluke Engineering Company, John	81
General Ceramics & Steatite Co.	3
General Electric Company	8
Greer Hydraulics Inc.	6
Helipot Corporation	7
Hudson Radio & Television Corp.	80
Industrial Control Company	85
Isotopes Specialties Co., Inc.	85
Kollmorgen Optical Corporation	68
Lambda Electronics Corp.	83
Leitz, Inc., E.	65
Magnatran Incorporated	84
Marion Electrical Instrument Co.	5
Minneapolis-Honeywell Regulator Co.	62
Mycalex Corporation of America	62
National Radiac	86
Nuclear Instrument & Chemical Corp.	Fourth Cover
Nuclear Research Corporation	69
Optical Film Engineering Co.	85
Penberthy Instrument Co.	80, 87
Radiation Instrument Co.	86
Radioactive Products, Inc.	74
Raytheon Manufacturing Company	2
Resistance Products Co.	84
Searchlight Section	87
Sorensen & Company, Inc.	79
Technitrol Engineering Co.	81
Tracerlab, Inc.	57
United States Gasket Co.	88
United States Radium Corp.	78
Victoreen Instrument Co.	67
Waterman Products Co., Inc.	63
Where to Buy	87

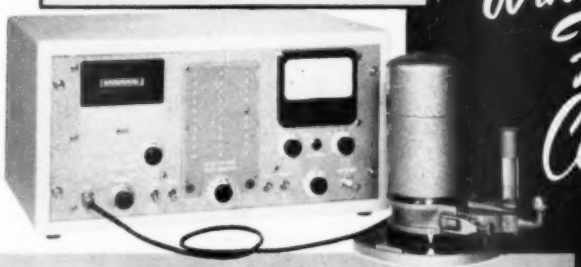
•

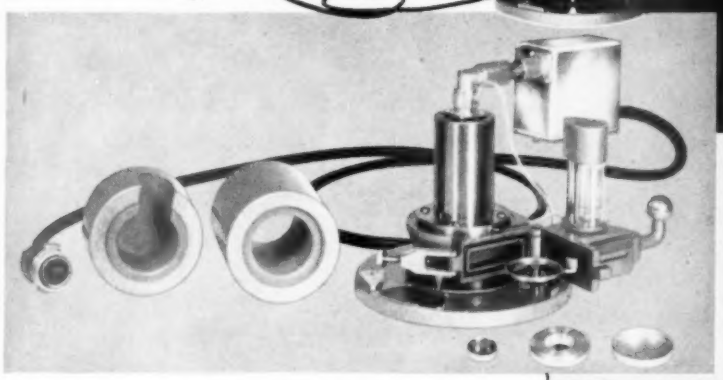
SEARCHLIGHT SECTION
(Classified Advertising)
H. E. Hilty, Mgr.

EMPLOYMENT 87
BUSINESS OPPORTUNITIES 87

This index is published as a convenience to the readers. Every care is taken to make it accurate, but NUCLEONICS assumes no responsibility for errors or omissions.

ATOMIC'S





Windowless Flow Counter } MODEL 952 for

- Geiger or Proportional counting
- alpha or beta particles
- solid samples

The Model 952 flow counter provides a means for efficient counting of alpha and beta particles by insertion of solid samples into the sensitive volume of the counter. Excellent stability and fast change-over of samples is achieved without contamination of the counting chamber by automatically sealing the chamber while the counter is in the *load* position. After insertion of sample, a *flush* time of only 15 seconds is required before *count* commences. After prolonged inactivity, only 15 minutes flush time is required before use.

The counter is available with either 1" or 2" diameter cathodes. When the 2" cathode is used, the chamber will accommodate 1" or 2" samples (adapter furnished). With proper gas mixtures, the counter may be used in either the Geiger region, or in the proportional region which allows alpha particles to be counted in the presence of a beta or gamma background.

The Model 952 utilizes a conical seal in the chamber to insure a long gastight life. Negligible leakage of the counter allows many extra months use from a tank of counting gas. Another unique feature is that the counting rate is independent of variations in the gas flow rate.

Operational characteristics in Geiger region:

Plateau length: greater than 150 volts
Plateau slope: approximately 2% per 100 volts after 15 minute flush (1" cathode)
Resolving time: 125 ± 25 microseconds
Counting gas: Geiger — 99% Helium, 1% Isobutane
Proportional — 96% Helium, 4% Isobutane

Related equipment:

As a Geiger counter — Atomic's Model 1020A, 1030A (shown) or 1060A scalers
As a proportional counter — Atomic's Model 216 Preamplifier (shown above) and Model 1040A, 1050A or 1070A scalers

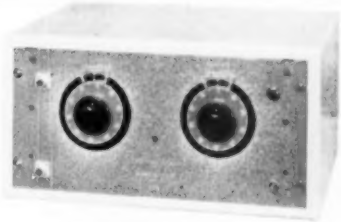
"TEN - TEN" Scalers

. . . to fit your needs without high "custom design" costs

There's no need to purchase high-cost "custom design" scalers to fulfill your particular scaling needs. Now, with Atomic's "TEN-TEN" Series, you can have a regular production model scaler at modest cost, but with added features built into each of the seven basic models to modify the unit to your specifications. Simply choose your basic scaler, by the scaling factor, input sensitivity and choice of automatic or manual control. Then select the additional features you require from the list of many options available for these scalers.

PULSE HEIGHT ANALYZERS Model 510 Single Channel Differential Pulse Height Analyzer is designed for the study of the amplitude distribution of electrical pulses within the range zero to 100 volts. The 510 will accept pulses falling between two set amplitudes. The channel "baseline" is adjustable from zero to 100 volts by helical potentiometer, and the "window" is settable from zero to 7 volts wide by a second helical potentiometer.

NEW MODEL 520 Twenty Channel Differential Pulse Height Analyzer speeds the taking of accurate data on the amplitude distribution of electrical signals having random amplitude and random time distributions by simultaneously accepting and recording pulses in each of the twenty discriminator circuits.



Model 510 Single Channel

Send for the Atomic illustrated catalog 952-1

ATOMIC INSTRUMENT COMPANY
84 MASSACHUSETTS AVE. CAMBRIDGE 39, MASS.

Linear Amplifiers, Scalers, High Voltage Supplies, Scintillation Counters, Count Rate Meters, Coincidence and Anticoincidence Instruments, Differential Pulse Height Analyzers, Accessories

SALES AND SERVICE REPRESENTATIVES
RON MERRITT COMPANY · Seattle, Washington
RESEARCH EQUIPMENT & SERVICE · Chicago, Ill.
KITTLESON COMPANY · Los Angeles 46, Calif.
Branch Office: Albuquerque, New Mexico
PROFESSIONAL EQUIPMENT CO. · New Haven, Conn.
Branch Office: New York, N. Y.
W. A. BROWN & ASSOC. · Alexandria, Virginia
Branch Offices: Atlanta, Ga., Charlotte, N. C., Tampa, Fla.
CANADIAN MARCONI, LTD. · Montreal, P. Q., Canada
Branch Office: Toronto, Ont., Canada

Be sure to visit Booths 4 - 109, 110 I.R.E. Show, March 23-26, N. Y. C.

Want more information? Use post card on last page

A NEW nuclear SCALER

Model 182

with these OUTSTANDING ADVANTAGES FOR YOU:

You can be sure of higher accuracy in your counting work, with the greater dependability, greater flexibility, and greater convenience built into Nuclear's completely re-engineered Model 182 scaler.

- Wide sensitivity range with linear amplification from 1 millivolt to 1 volt handles proportional, scintillation, and geiger counters.
- New wide range amplifier circuit has a rise time of less than 0.2 microseconds, overshoot less than 10%, and a large dynamic range to eliminate D. C. level shift. Cathode follower circuit provides low capacity input and electronic cut-off to prevent overloading.
- Choice of 500 to 5000 or 500 to 2500 volts continuously variable to meet your needs. Drift-free circuit having less than .002% change in high voltage for a 1% line voltage change. Potted high voltage transformer assures long life in any ambient condition.
- New switch arrangement provides Standby H. V. and 60-Cycle Test positions.
- Built-in register and timer electrically reset for added convenience.
- Chassis slope-mounted in cabinet for easier reading — may be installed in relay rack if desired.

Write today for full information about Nuclear's Model 182 Scaler.

nuclear INSTRUMENT & CHEMICAL CORPORATION

235 West Erie Street • Chicago 10, Illinois

Branch Offices:
New York, New York — Los Angeles, California — Silver Spring, Maryland

Export Department:
13 E. 40th Street, New York 16, N. Y.

Cable Address:
Arlab, New York

- Scaling Units for Every Type of Radiation Counting
- Complete "Packaged" Counting Systems
- Health Monitoring Instruments for Personnel Protection
- Glass Wall, Mica Window, and Windowless Counters
- Portable Count Rate Meters
- Radioactive Chemicals
- Complete Line of Accessories for the Nuclear Laboratory

nuclear "PRECISION INSTRUMENTATION FOR NUCLEAR MEASUREMENTS"

Want more information? Use post card on last page.